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FINAL REPORT

August 1977

Submitted to the

Energy Research and Development Administration
through the
U.S. Department of Agriculture
and to the
Georgia Institute of Genetics

from

Georgia Institute of Technology
225 North Avenue, N.W.
Atlanta, Georgia 30332

DESIGN OF COLLECTORS AND INSTRUMENTATION FOR APPLICATION TO SOLAR DRYING OF PEANUTS, TOBACCO AND FORAGE

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I. INTRODUCTION

In the second year of this project the progress which had been made in the first year was consolidated and continued. Work has continued on the solar pond collection system and the solar greenhouse collector system as well as using solar energy to assist in methane production with the methane being used for crop drying. The instrumentation system has been switched from a mini-computer to a microprocessor. In addition, the work begun last year in evaluating the transmissivity, absorbtivity, durability, thermal properties and cost of solar materials has been continued.

The concepts of the black-film hot air collector and the integrated rock collector and storage system have been combined to form one system which is called the Augmented Integrated Rock System or AIRS. Work has begun on the construction of a 1,200 square foot AIRS. This unit will have a 720 square foot black film hot air collector feeding into a 480 square foot integrated rock storage and collection system. The rocks will be piled to a depth of 12 inches and this 24 tons of rock will be able to store 1 million BTU's at a ΔT of 100°F. The AIRS offers the combined advantages of the black film hot air collector and the integrated rock storage and collection system.

II. MATERIAL SELECTION

An important part of the design of any solar agricultural drying system is material selection. For our collector designs, it is often necessary to make trade-offs such as durability versus cost. The materials considered as glazings were glass, PVC, Monsanto 602, Fiberglass Reinforced Plastic (Filon and Kal-Wall), Cellulose Acetate Butyrate (Tenite) and Tedlar. The insulators considered included 6" Fiberglass, 1" Fesco Board, 3/4" Styrofoam (Technofoam by Celotex), 3/4" Styrofoam (DOW), and 5/8" Polystyrene. The candidate absorbing materials were Polyethylene, Typar (3 formulations) Tar Paper, Black Paper, and Blackened Aluminum Foil. The three storage mediums considered were water, rock and iron.

Glazing

In choosing a glazing material for a solar collector, the most important items to consider are cost, transmissivity, durability and heat retention.

The costs of several candidate materials are shown in Figure 1. These costs are, in general, from local Atlanta suppliers and may vary in other parts of the country.

Transmissivity tests on candidate materials were performed according to the National Bureau of Standards Specifications 21387-1973. A typical plot of the data from one transmissivity test run is shown in Figure 2 and a table of the test results is shown in Figure 3.

FIGURE 1

MATERIAL	COST PER SQUARE FOOT
Glass	$.45-$1.00
Low Iron Glass "Waterwhite"	$2.00
PVC (10 Mill)	$ .30
Monsanto 602	$ .02
Fiberglass Reinforced Plastic	$ .45
Tenite (Cellulose Acetate Butyrate)	$ .03
Tedlar	$ .35

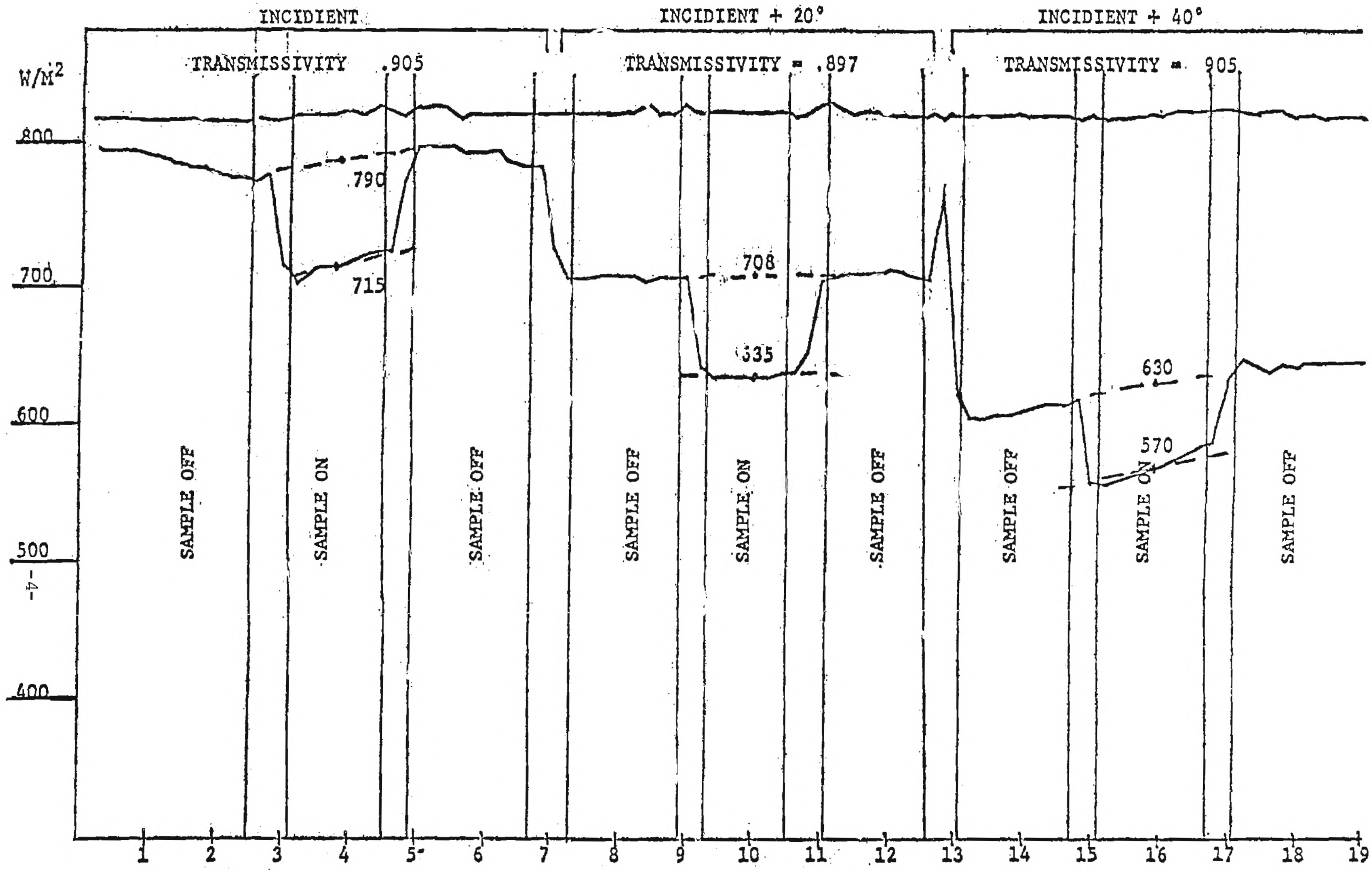


FIGURE 2 TRANSMISSIVITY OF CLEAR 10 MIL TENITE BUTYRATE

FIGURE 3

MATERIAL	TRANSMISSIVITY		
	DIRECT RADIATION	20° RADIATION	40° RADIATION
Kalwall	.881	.875	
PVC	.937	.862	
Tedlar	.919	.826	
Monsanto 602	.903	.841	
Fiberglass	.815	.813	.781
Fiberglass (Cross Grain)	.815	.796	.878
Tenite PTMT	.907	.898	.884
Tenite Butyrate	.905	.897	.905

The ideal glazing material would be perfectly transparent to radiation in the solar spectrum (wavelengths .2 - 2.6 um) and opaque to all radiation with longer wavelengths. Two tests were used to test for these properties, the spectral density of each material was evaluated using a Perkin-Elmer Model 700 Spectrophotometer. Results of one of these tests on M602 are shown in Figure 4. In addition, a test chamber was constructed with four compartments so that four samples can be exposed to identical radiation. The rise and fall of temperatures inside the absorption chambers over 30 minutes is shown in Figure 5.

The expected life-span of various glazings when exposed to U.V. radiation and normal weather conditions is shown in Figure 6. It should be recalled that when using double glazing the lower glazing is exposed to less severe weather conditions and would therefore have a longer expected life span than shown in Figure 6. It should be noted, however, that the tenite will degrade (become brittle and shatter) in about one month if exposed to high temperatures (200°C). It could therefore be used as the top glazing in a double glazed system.

Insulators

The most important properties of insulating materials are cost, durability and thermal resistance. Thermal resistance is expressed in "degrees per BTUh per square foot." It is the temperature drop expressed in degrees Fahreheit through the insulating material when heat is passing through it at the rate of 1.0 BTU per square foot of surface per hour. The total thermal resistance of any heat barrier is the sum of the thermal resistance of its parts.

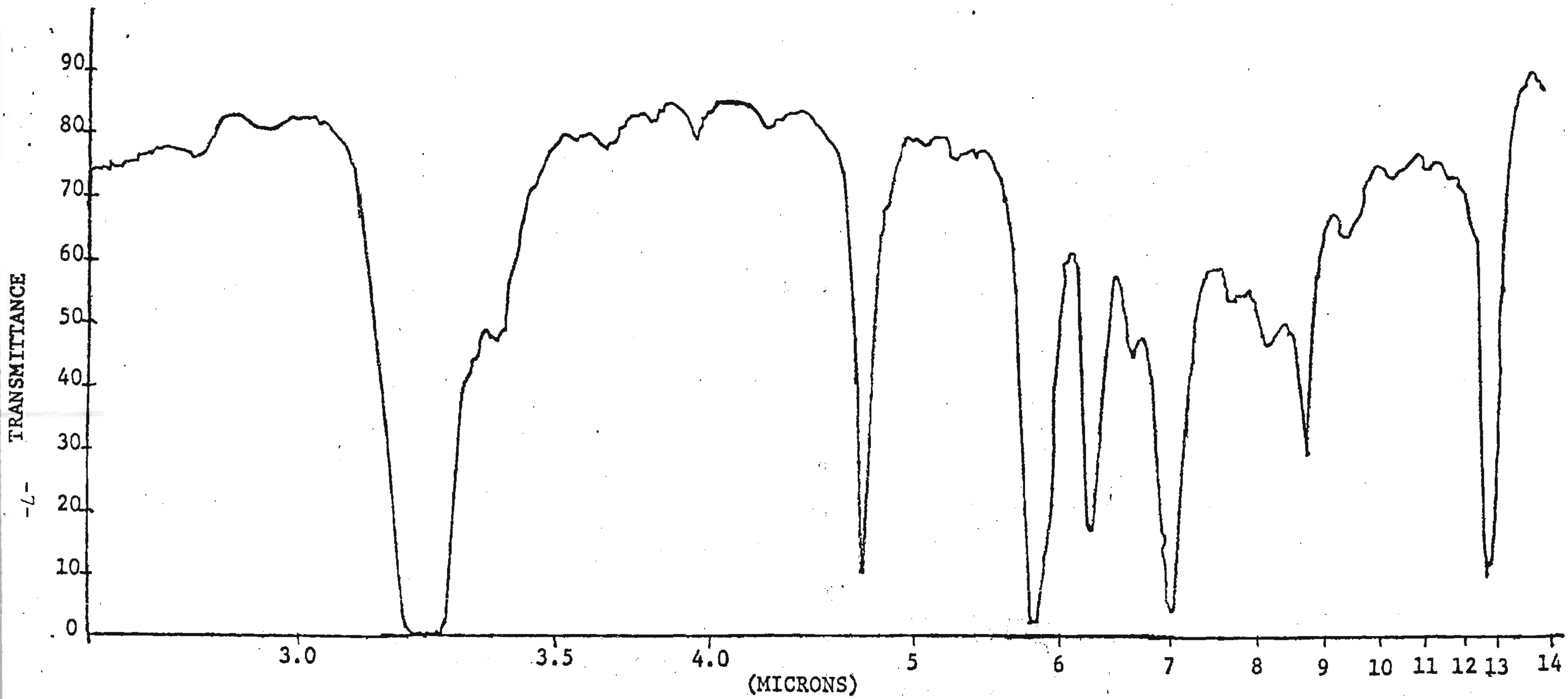


FIGURE 4 TRANSMITTANCE OF MONSANTO - 602 UV RESISTANT POLYETHYLENE

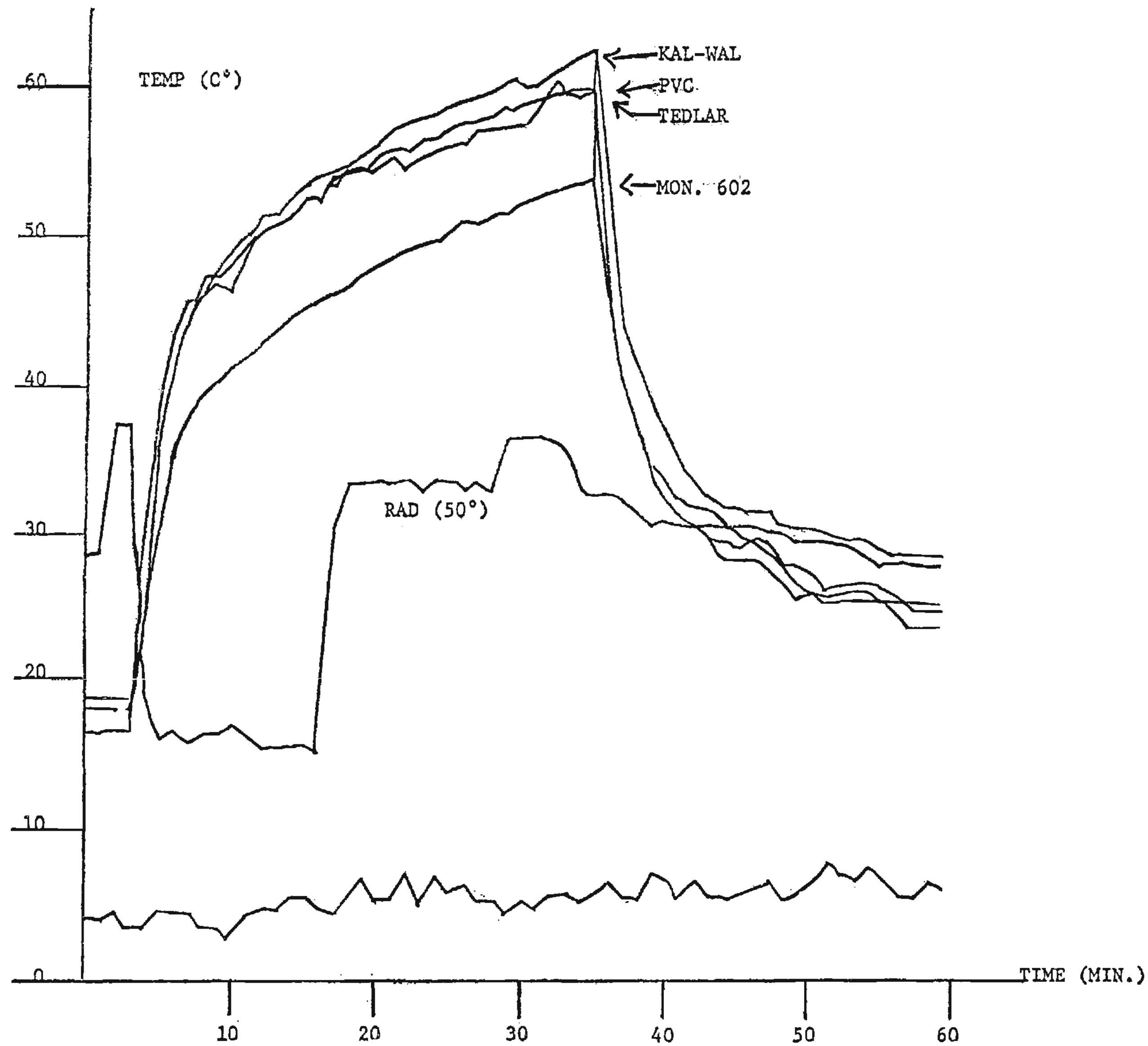


FIGURE 5 TEMPERATURE RISE IN AN ABSORPTION CHAMBER WITH FOUR GLAZING MATERIALS

FIGURE 6

MATERIAL	EXPECTED LIFE IN YEARS
Glass	20+
PVC (10 Mill)	1
Monsanto 602	2
Fiberglass Reinforced Plastic	10
Tenite	10
Tedlar	20

The conductance of a material or its U value is the inverse of its thermal resistance.

$$U = \frac{1}{R}$$

The U value is measured in BTU's of heat flow per square foot per degree F temperature difference. Therefore, the smaller the U value of a material, the better it is as an insulator.

The durability of an insulating material depends on the conditions to which it is exposed. Most materials lose their insulating value when wet. Some are protected with a moisture barrier to prevent them from becoming wet. An insulating material should not lose its thermal resistance or deform under the greatest temperature range to which it might be subjected. (-30°F - 300°F is a possible range for nonfocusing solar collectors.) The degree of structural strength and the resistance to abrasion required are also functions of the application.

Figure 7 compares the cost per square foot and R value of some common insulators.

<u>Absorbing Materials</u>

A good absorbing material should have a high absorbtivity, a high melting point and a high thermal conductivity. It should also present a large surface area to the heat transfer fluid (i.e. air or water). This would imply that, in general, it is preferable to have a rough surface or corrugated surface to a flat surface. As with all materials, cost plays an important role in material selection.

FIGURE 7

WOOD	COST/FT^2	R
6" Fiberglass Craft Back	.13	19
1" Fesco Board	.20	2.78
3/4" Styrofoam (Technofoam by Celotex)	.35	8
3/4" Styrofoam (Dow)	.35	5.4
5/8" Polyestyrene	.20	4

The materials that have so far been tested as possible absorbing materials are black polyethylene, tar paper, black painted paper, black painted aluminum foil, and various formulations of a Dupont material called Typar. Of these materials, the Typar and the black polyethylene had the best absorbing characteristics, as shown in Figures 8 and 9. The black polyethylene was found to melt when exposed to high temperatures for a long period of time, and therefore the Typar appears to be the best available absorber.

Storage Mediums

Since agricultural drying must usually proceed for 24 hours a day and solar radiation is available only 8-10 hours per day, some method of energy storage must be employed. The choice of storage media is usually between storing sensible heat in either water or rock.

In general, the choice of a storage media is dependent upon the characteristics of the solar system, the amount of energy to be stored and the costs of implementing the storage. Figure 10 compares the heat capacity and density of water, rock and iron.

From this table it can be seen that in a given cubic foot of space about twice as much heat can be stored in water than in rock. Iron can store about 3/4 as much heat as water in the same volume. Thus, if space is the primary consideration, water is the storage media of choice.

However, the costs of implementing a water storage system usually exceed the costs of implementing a rock storage system. In addition to their low price, rock storage units have the desirable characteristics that the heat transfer coefficient between circulating air and the rocks

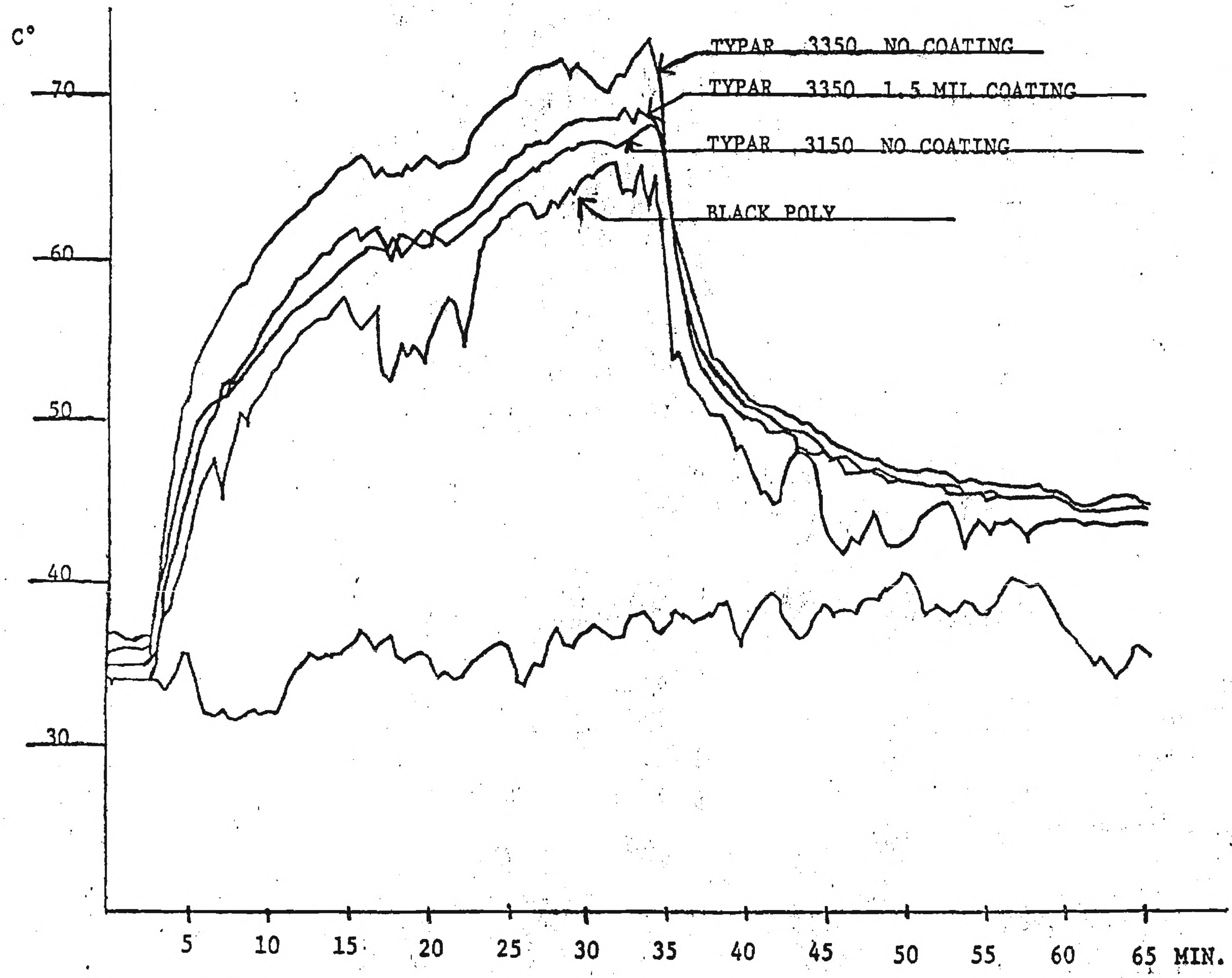


FIGURE 8 TEMPERATURE RISE IN AN ABSORPTION CHAMBER WITH FOUR ABSORBING MATERIALS

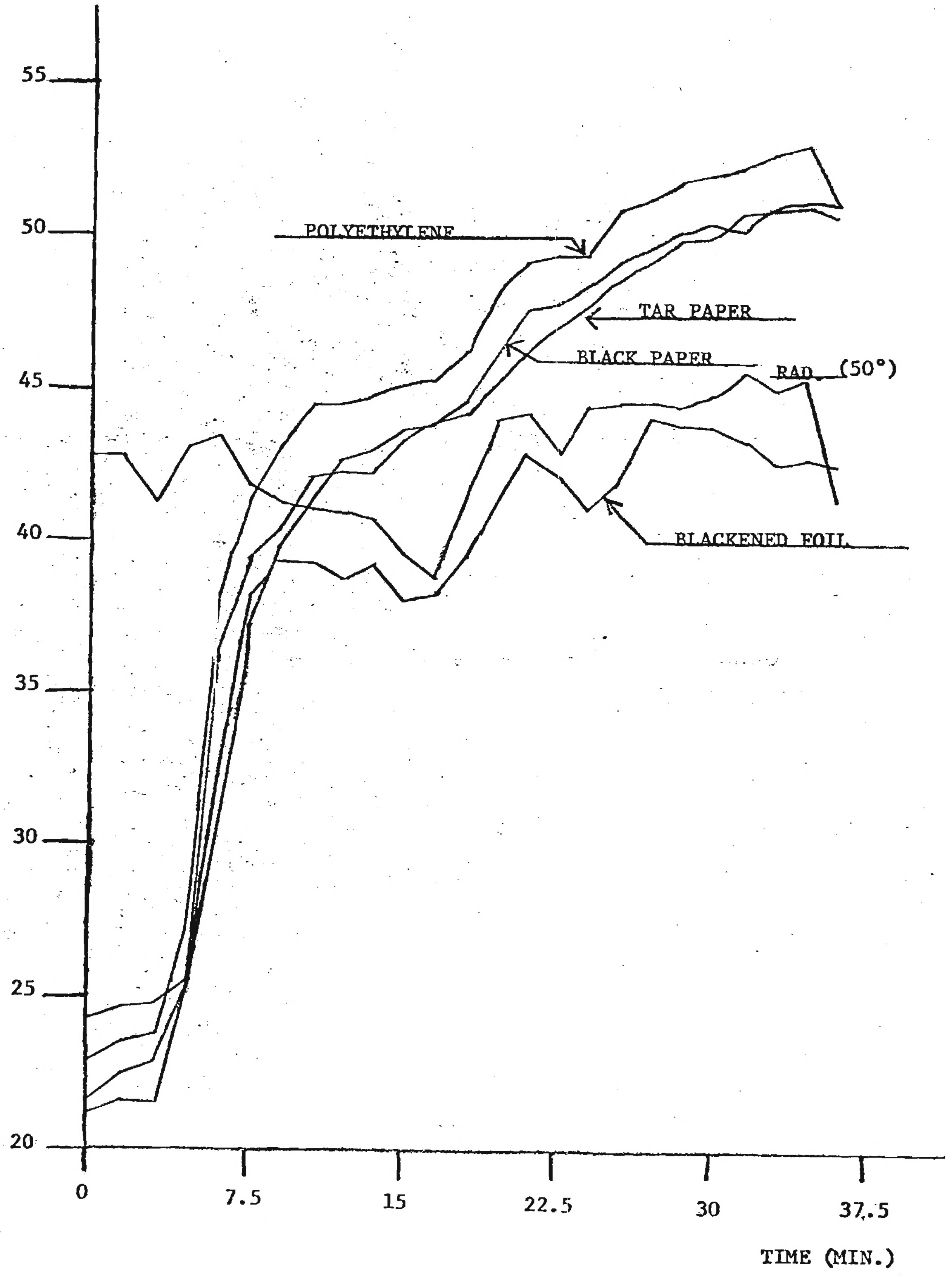


FIGURE 9 TEMPERATURE RISE IN AN ABSORPTION CHAMBER WITH FOUR ABSORBING MATERIALS

FIGURE 10

	C_p	DENSITY
	KJ/Kg°C	Kg/m^3
Water	4.19	1000
Rock	.88	2500-3500
Iron	.50	7860

is high, and the conductivity of the bed is low when there is no air flow.

In constructing a rock bed, rocks from 1 to 15 cm have been used. The rocks should be uniform in size so that pressure drops will be minimized.

III. INTEGRATED ROCK-STORAGE AND COLLECTION SYSTEM

By blackening the top layer of a rock bed and covering it with an appropriate glazing material, one can construct both an efficient collector of solar radiation and an inexpensive storage system as shown in Figures 11 and 12. The heat, however, tends to be concentrated near the surface of the rock bed. Tests have shown that without air circulation, the heat will penetrate only about 6 inches into the bed. Figure 13 illustrates the temperature profile within a test system during a period of 11 hours without air circulation.

Circulating air through the rock bed in a downward direction during the collecting period is desirable because surface heat is thus conveyed to the lower rock layers creating a more uniform temperature distribution. The more uniform distribution of heat will lower the rate at which heat is radiated from the system.

It has been determined that in order to achieve an average rock temperature of 60°C (with air circulation), the rock bed thickness should be no more than 0.3 meters. As the rock depth is increased beyond this figure, the collecting surface is not large enough to raise the temperature of the rock to a sufficiently high temperature for crop drying. In order to obtain more storage without increasing the surface area of the rock it is desirable to supplement this system by using the black film hot air collector described in the following section.

Double glazing is used for the rock bed system because it becomes imperative to have the rocks well insulated in order to preserve the

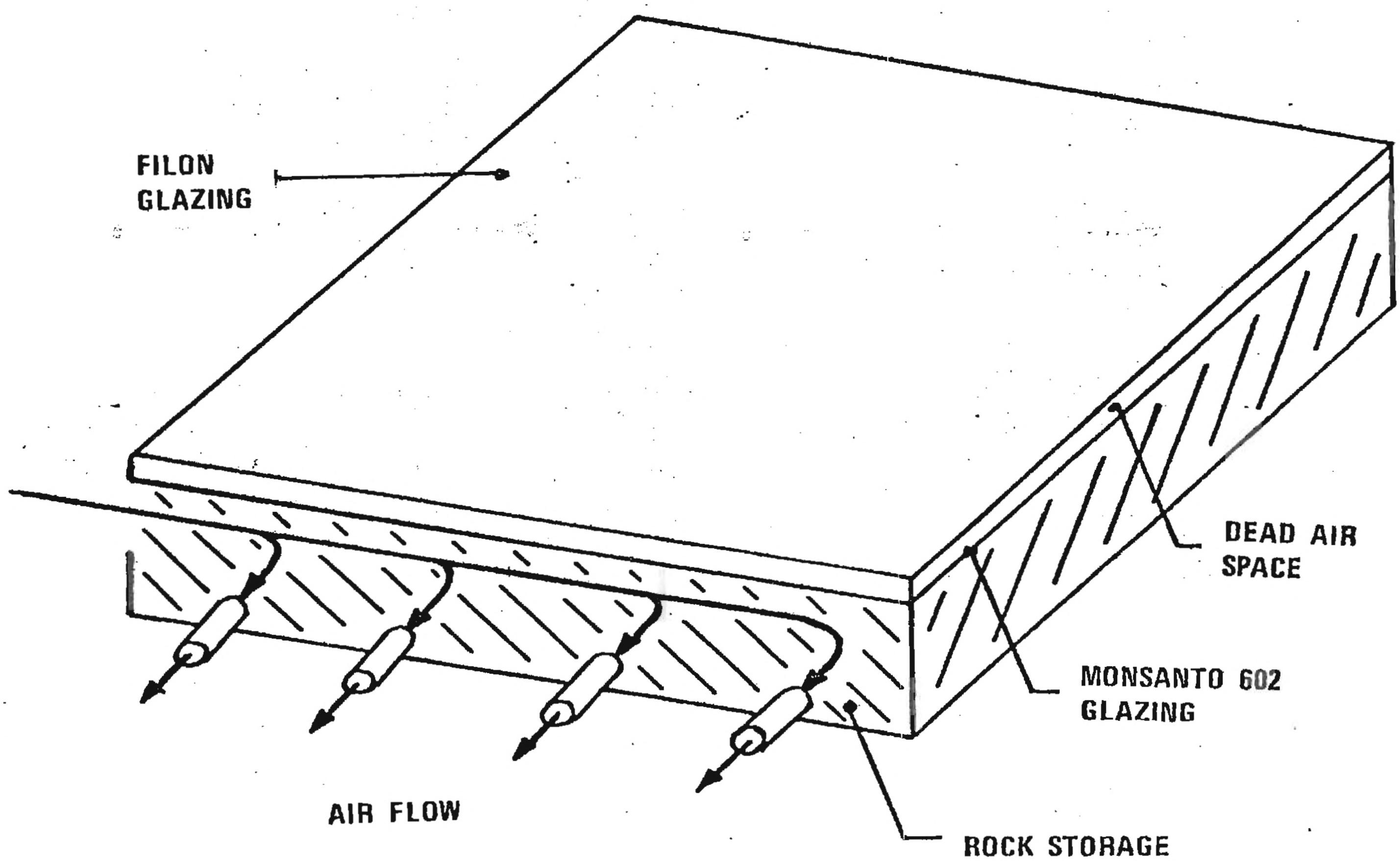


FIGURE 11. INTEGRATED ROCK STORAGE AND COLLECTION SYSTEM

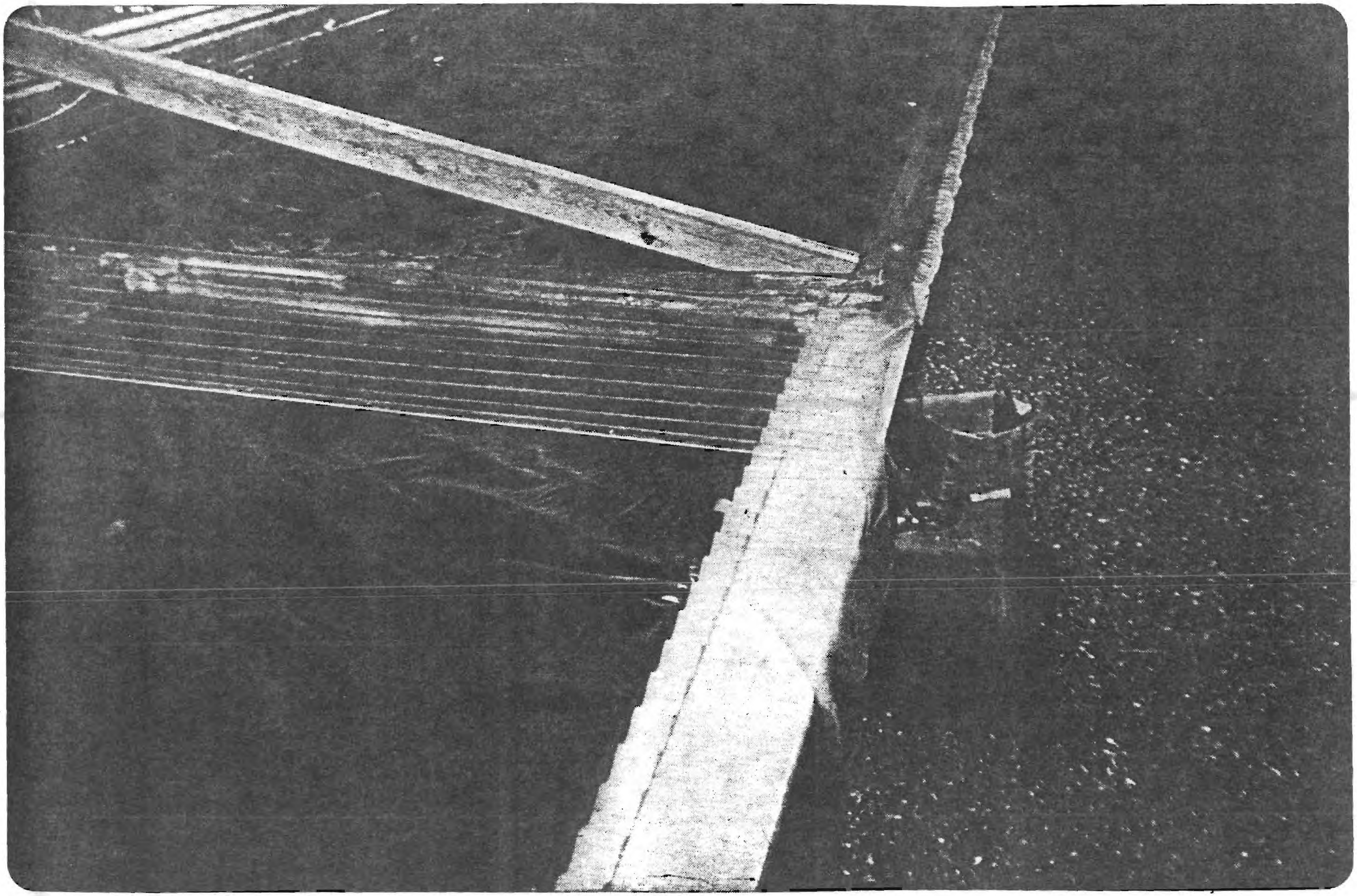


FIGURE 12
PHOTOGRAPH OF INTEGRATED ROCK-STORAGE AND COLLECTION SYSTEM WITH A PORTION OF THE COVER REMOVED

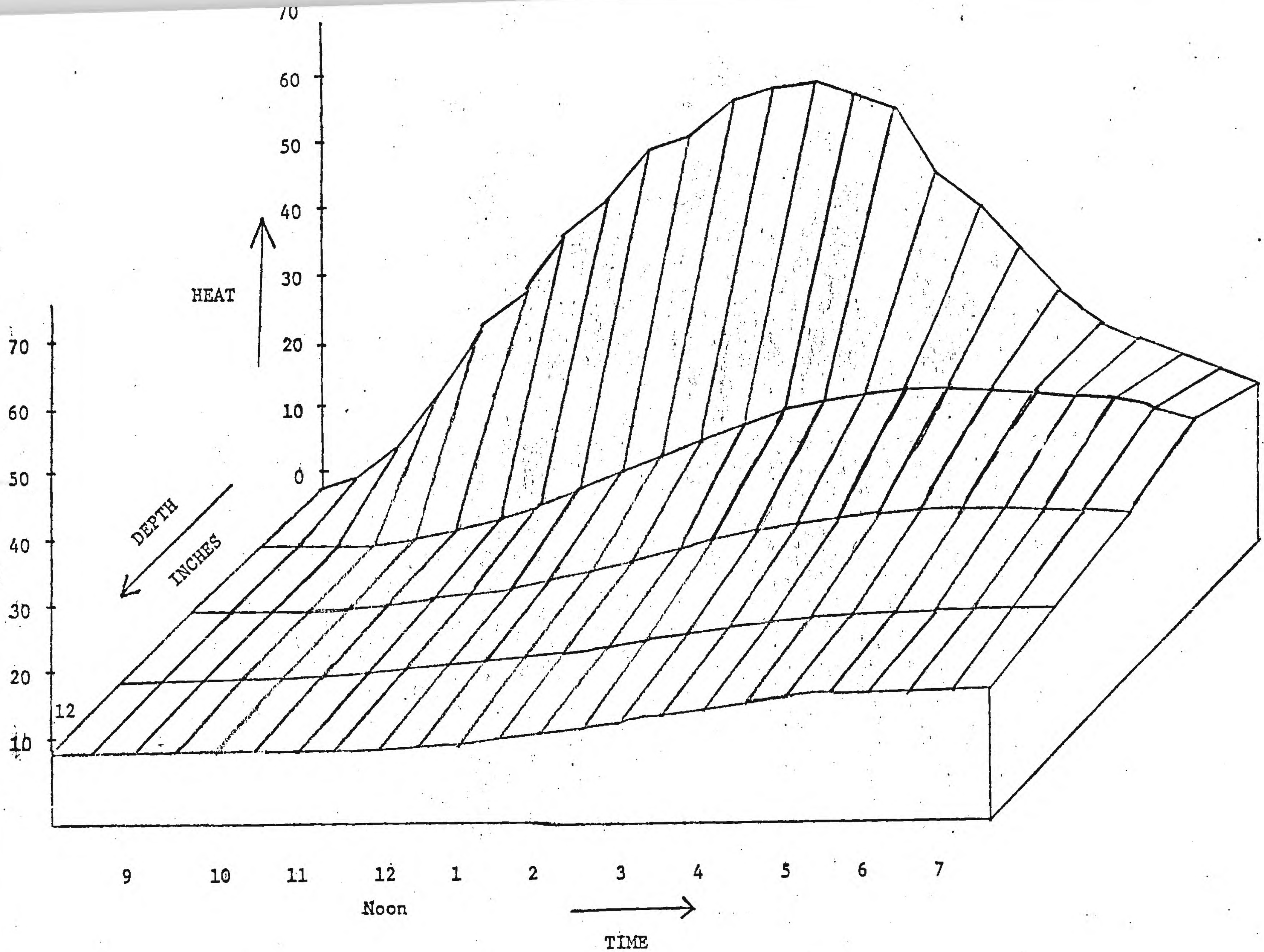


FIGURE 13. TEMPERATURE PROFILE OF ROCKS WITH NO AIR FLOW

built-in storage capability. The upper layer of glazing is fiberglass coated with Tedlar. This material is used because it is more opaque to infrared radiation than plain plastic and has an expected life span of 10 years. The lower layer of glazing is Monsanto 602 plastic. The Monsanto 602 is much less expensive than the fiberglass and since this layer will not be exposed to the elements or U.V. radiation its lifespan should exceed two years. The spacing between the two layers is about 2.5 cm, the spacing required to minimize heat transfer between the two surfaces. A smaller spacing results in smaller convective heat losses, but larger conductive heat losses. Increasing the spacing does not significantly change the amount of heat loss because as the conductive heat losses are lowered, the convective heat losses increase.

The rocks used in the system are granite and average 10 cm. in diameter. This size provides relatively good heat transfer properties because the rocks present a large surface area to the air stream and yet they do not unduley impede the air flow. It is important that the rocks be of uniform size to avoid impeding the air flow.

IV. BLACK FILM HOT AIR COLLECTOR

Two designs have been tested for the Black Film Hot Air Collector. They are shown in Figures 14 and 15. Figure 16 is a photograph of the two collectors taken while they were being tested.

The design shown in Figure 14 consists of a layer of glazing and a layer of blackened Fesco insulation. Air is drawn in between the glazing and the insulation and heated as it passes through the collector. The air is forced through the collector by a fan located at the base of the unit.

The design shown in Figure 15 consists of a layer of clear glazing, a 2.5 cm stagnant air gap, a layer of black Typar, a 5 cm space for hot air, and a layer of Fesco board insulation. Air enters at the top of the collector and is heated as it passes behind the Typar. The heat can then be stored in a rock storage bin. The air is moved through the collector by a fan located at the base of the unit. Typar was chosen as the absorbing material over black polyethylene, tar paper, black painted paper, and black painted aluminum foil. The Typar and the black polyethylene both have superior absorbing characteristics, but the polyethylene was ruled out because it melted at the temperatures encountered in the system.

The use of U.V. treated cellulose acetate butyrate as the glazing material looked promising for several months. This material is very clear, inexpensive and easy to handle. However, when exposed to the high temperatures within a collector (> 212°F) and then cooled down,

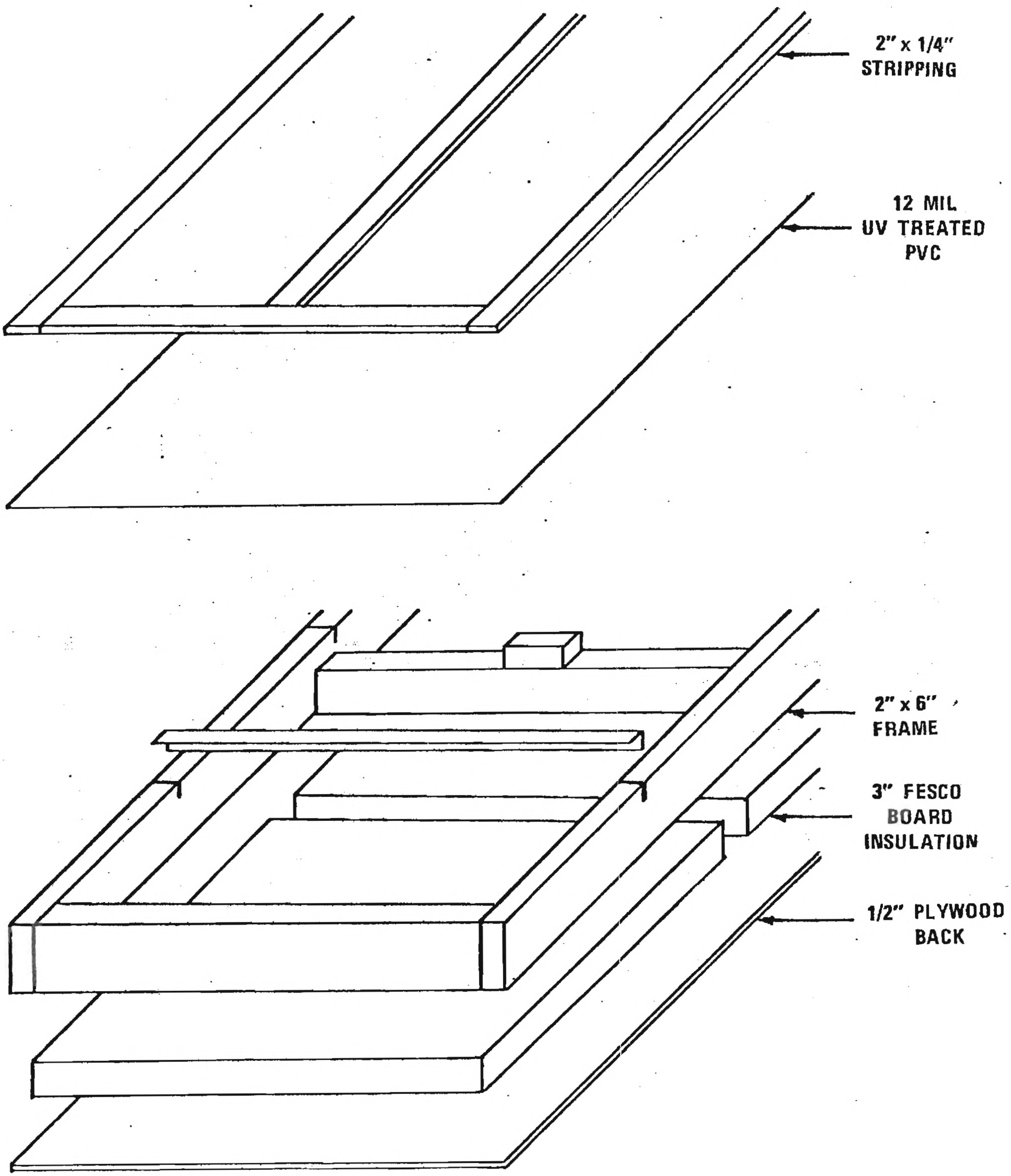


FIGURE 14. AIR DRYER CONSTRUCTION WITH BLACKENED FESCO AS THE ABSORBER.

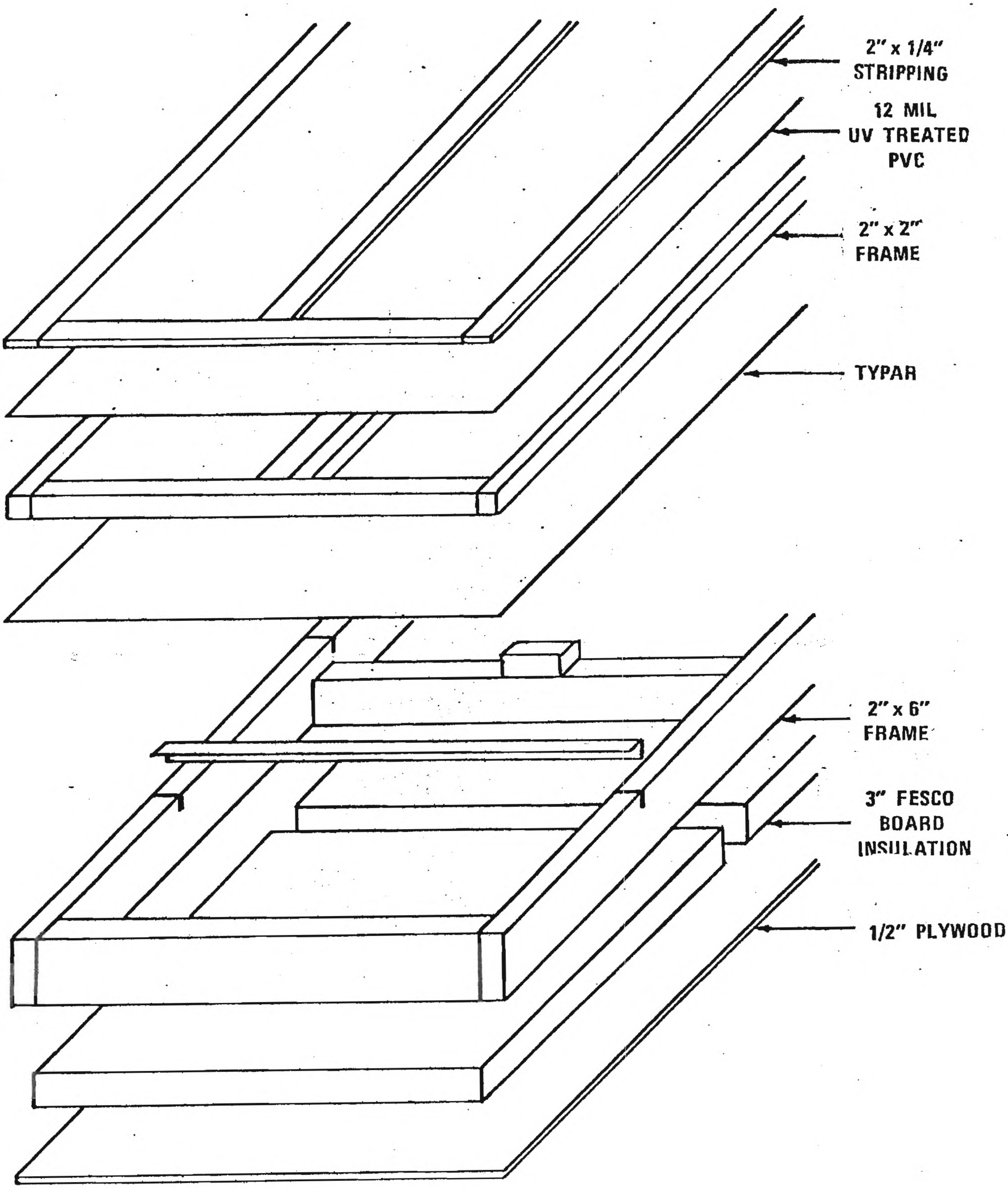


FIGURE 15. AIR DRYER CONSTRUCTION WITH TYPAR AS THE ABSORBER.

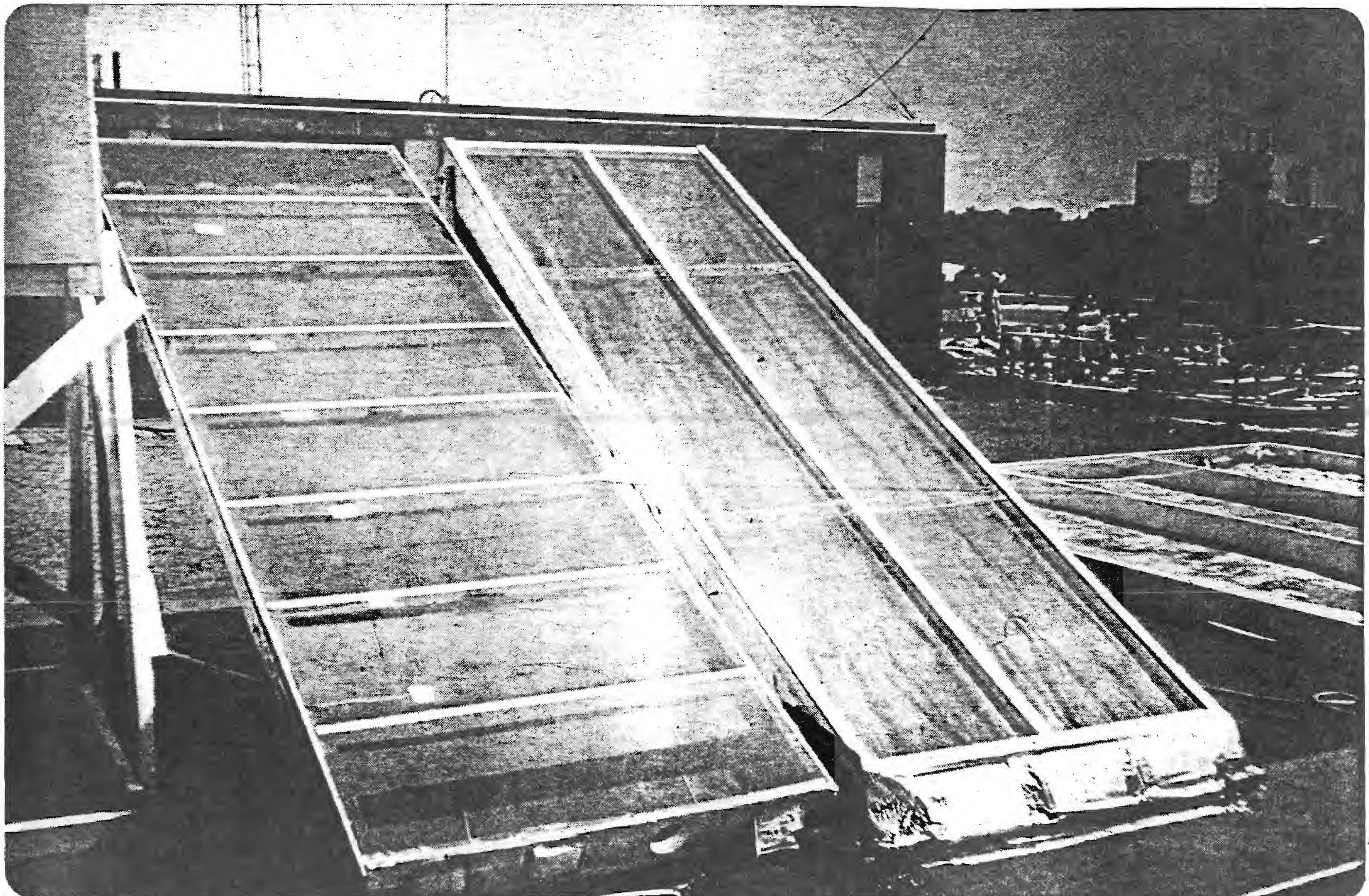


FIGURE 16
PHOTOGRAPH SHOWING TWO VERSIONS OF THE BLACK-FILM HOT AIR COLLECTORS WHILE UNDERGOING TESTS

it becomes extremely brittle and it is likely to disentegrate. An alternate material is a U.V. treated PVC sold under the trade name of Ceylon.

The graph in Figure 17 plots the temperature at the top of the collector design shown in Figure 14 over a 17 hour period along with the air temperature and the incident radiation. By comparing this with the performance of the other collector design shown in Figure 18, it can be seen that the second design has a significantly higher temperature rise. In actuality, the temperature curve for the second design is flattened at the top because the thermocouples which measured the temperature became saturated at 100°C.

The temperature within both collectors varied and Figure 19 illustrates this variation for several heights within the collector which has Typar as the absorber at different times of the day. Once again, the saturation of the thermocouples is apparent in this graph.

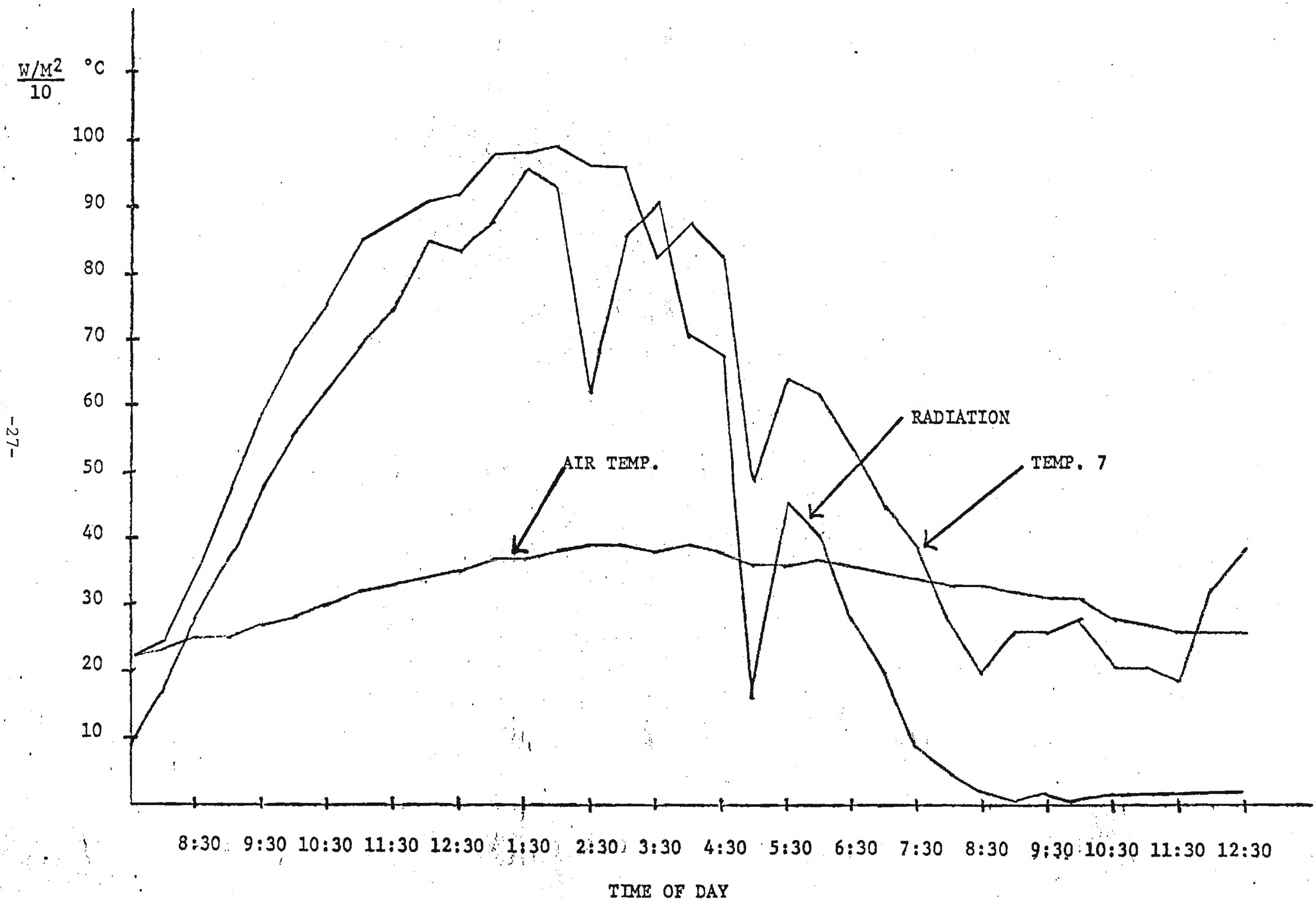


FIGURE 17. TEMPERATURE AND RADIATION CURVES OF AIR DRYER WITH BLACKENED FESCO

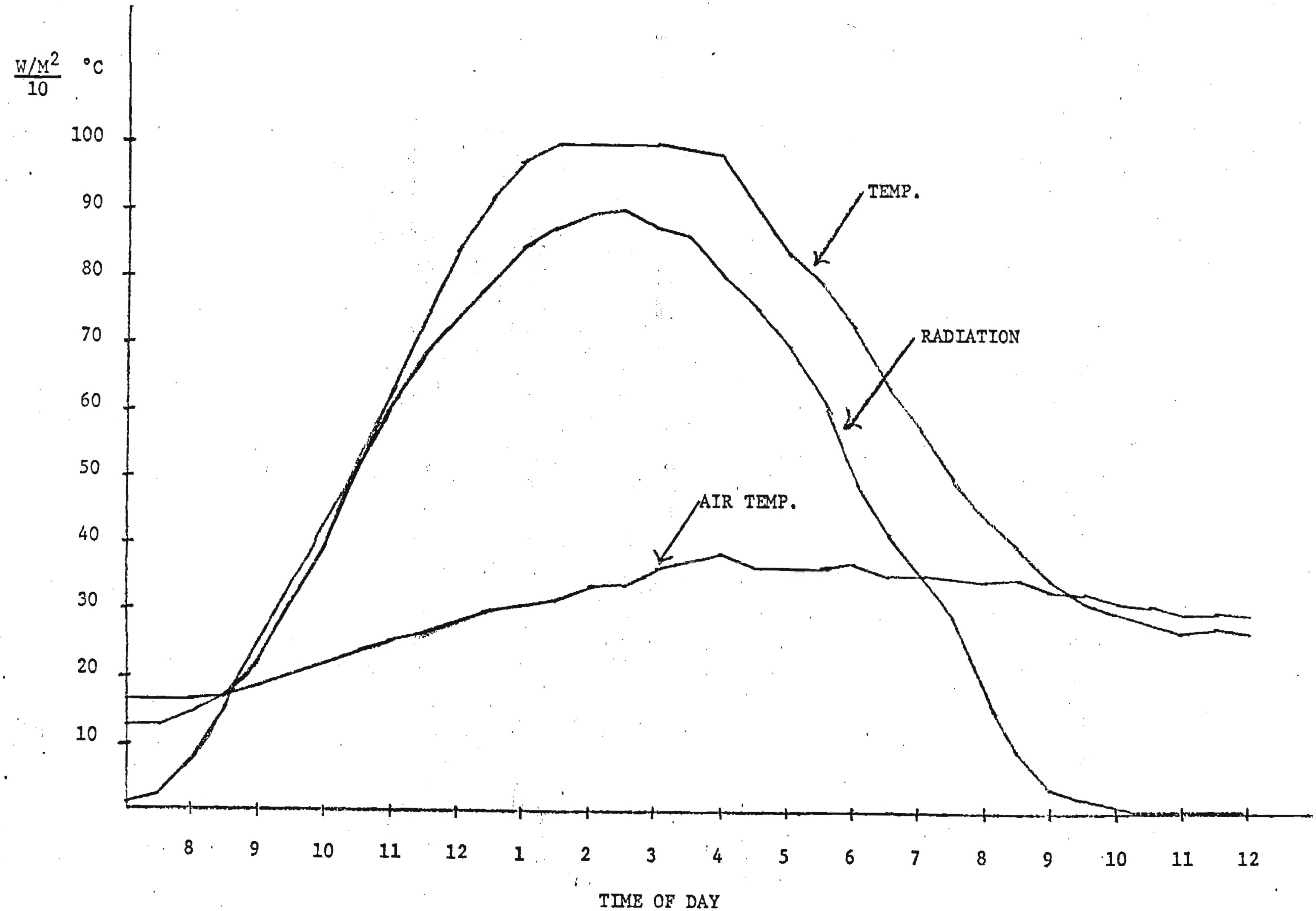


FIGURE 18. TEMPERATURE AND RADIATION CURVES OF AIR DRYER WITH TYPER AS THE ABSORBER

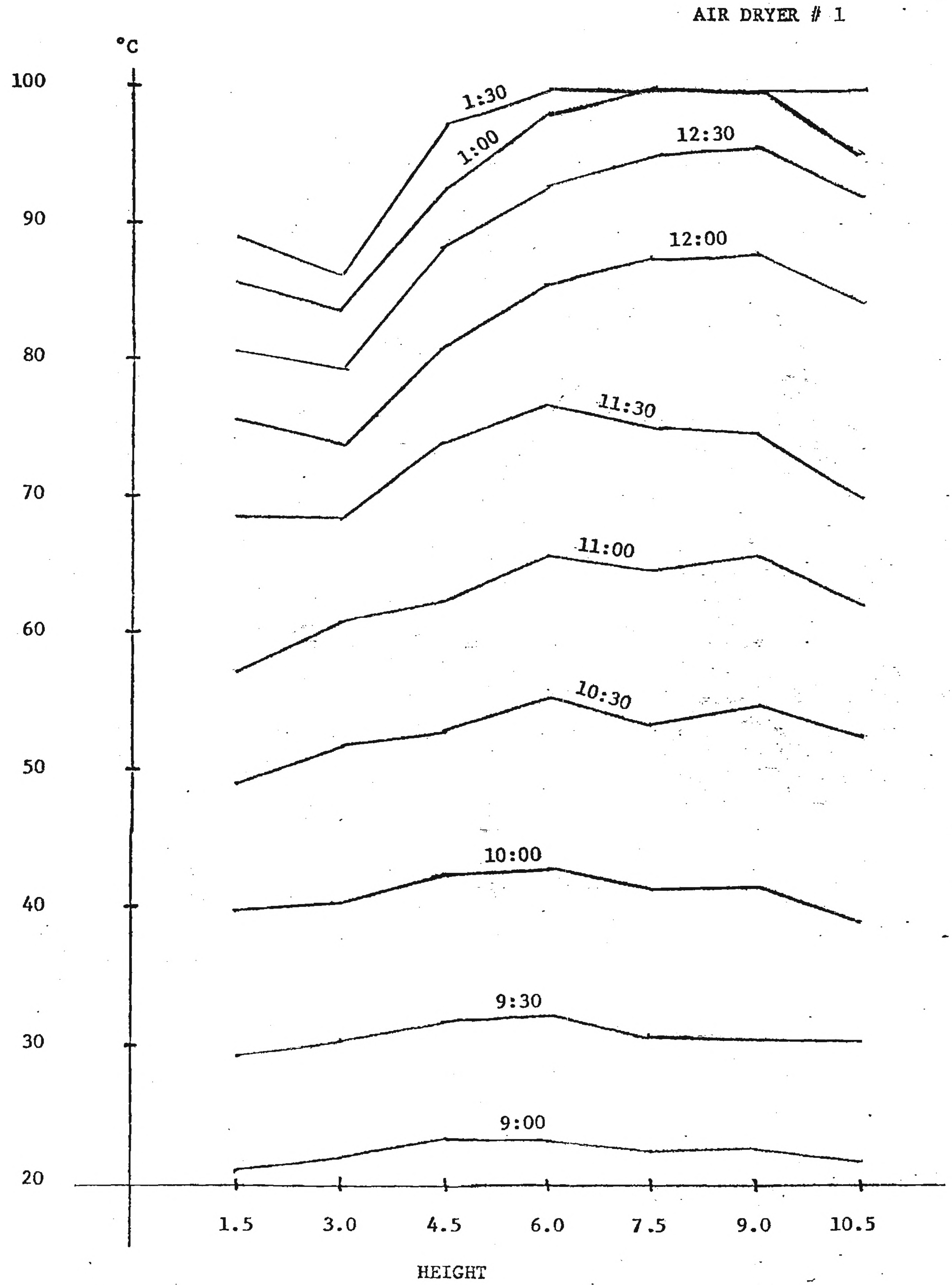


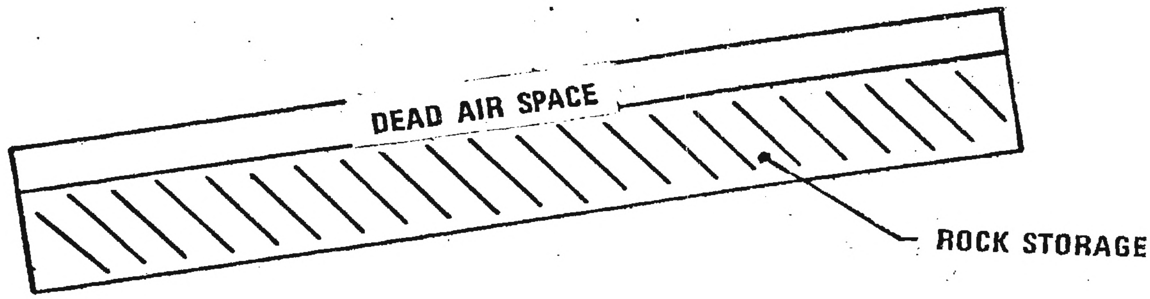
FIGURE 19. TEMPERATURE VS. HEIGHT FOR THE AIR COLLECTOR WITH TYPAR AS THE ABSORBER

V. AUGMENTED INTEGRATED ROCK SYSTEM (AIRS)

Combining the two solar collectors previously discussed provides a very inexpensive system with the advantages of both systems. The rock bed system cannot be placed at the proper angle to the sun without incurring the expense of grading the earth. It will also radiate energy from its entire surface area. By combining the two units as shown in Figure 20, you can have as much surface area as the top system shown in Figure 20 but more radiation will be intercepted because the black film hot air collector is at a high enough angle to intercept the maximum amount of the sun's radiation. In addition, the storage area has half of the surface area of the integrated rock system. On the other hand, if the black film hot air collector were used alone it would still require a storage unit and a conventional storage unit would not be acting as a collector.

A 1200 square foot AIRS, as illustrated in Figure 21, will be constructed this summer. It will have a 720 square foot (60 x 12) black film hot air collector connected in series with a 480 square foot (60 x 8) integrated rock storage and collection system. The rocks will be 12 inches deep and will be able to store about one million BTU's at a ΔT of 100°F. The ground has been graded so that the rock storage and collection system will face south at a 20 degree slope. The black film hot air collector will be placed at a 35° angle.

Figure 22 shows the air flow in the AIRS when it is operating in the energy storage mode. Air is forced by the fan into the top of the



INTEGRATED ROCK STORAGE

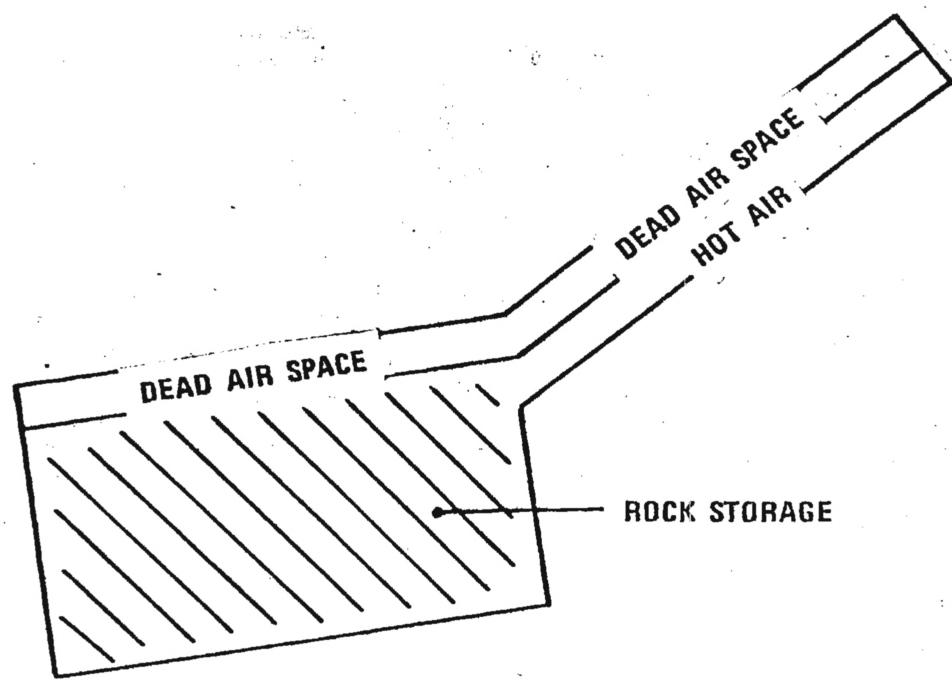


FIGURE 20. AUGMENTED INTEGRATED ROCK SYSTEM (A.I.R.S.)

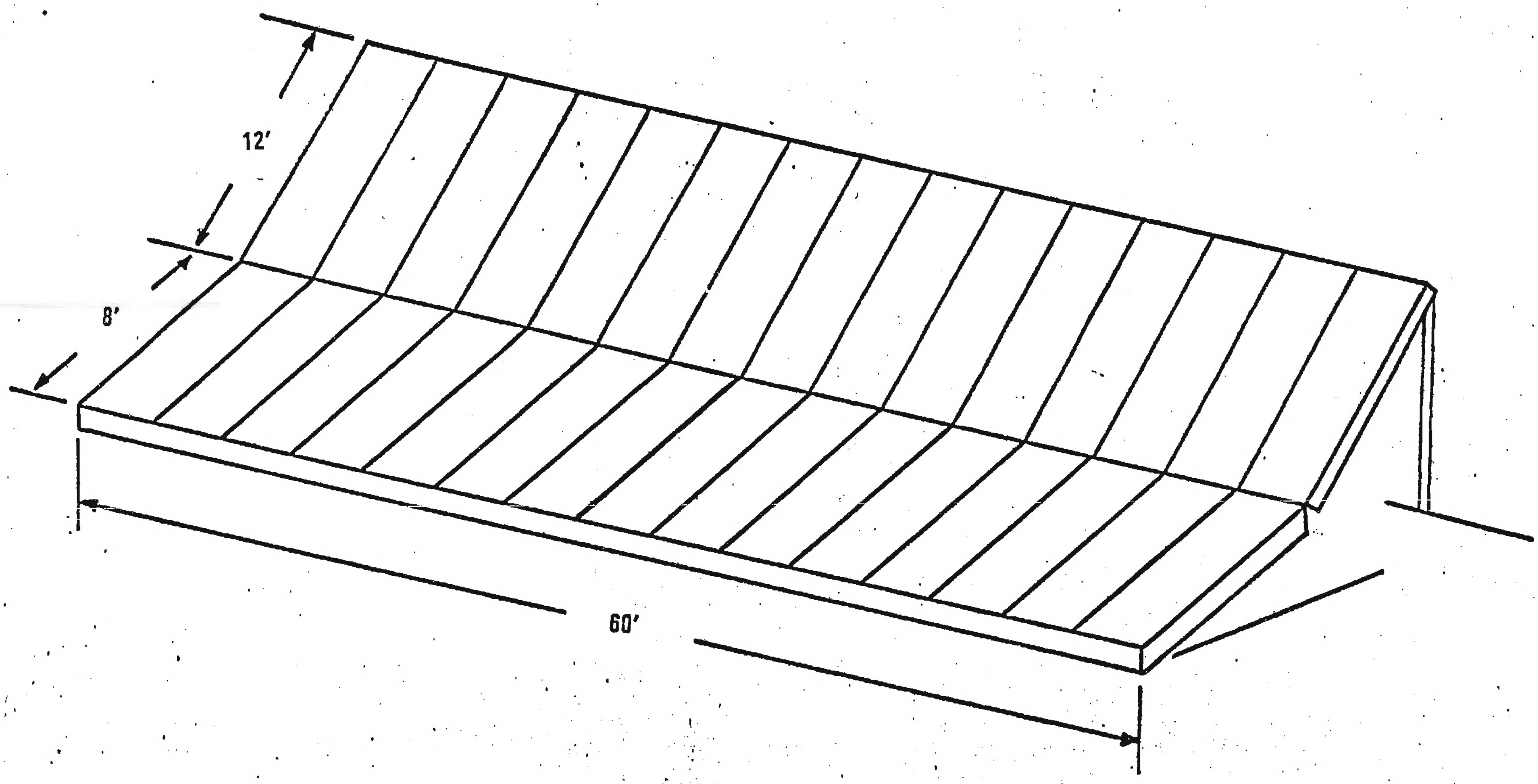


FIGURE 21. LAYOUT OF A.I.R.S. TO BE BUILT ON GEORGIA TECH CAMPUS

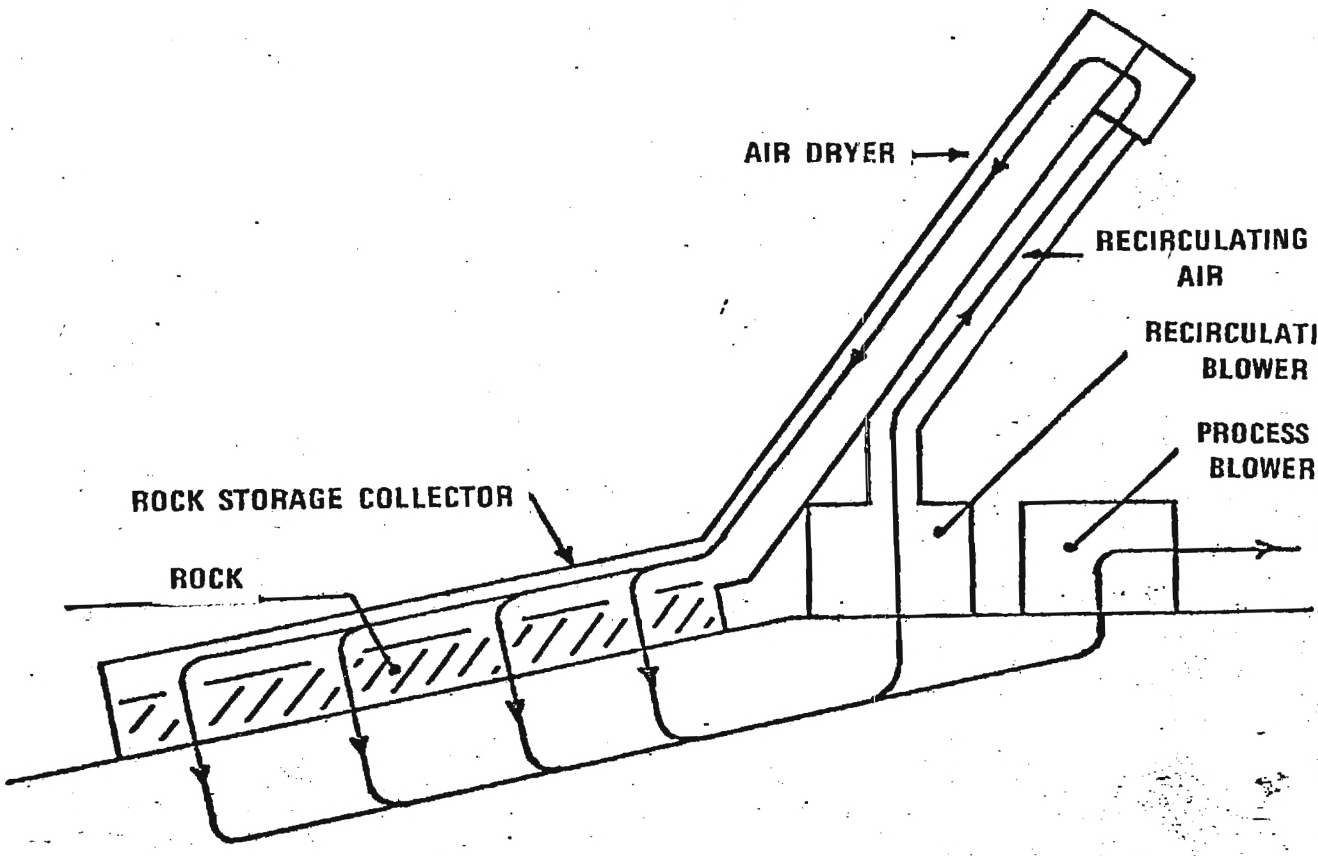


FIGURE 22. AIR FLOW IN THE A.I.R.S. SYSTEM

black film hot air collector where it is heated as it travels down the collector beneath the black Typar absorber. Upon entering the rock storage and collection system, it is heated further and forced down through the rocks. The air heats the rocks and then returns to the black film hot air collector. The second fan in the unit will force air into the drying wagon or shed.

The materials cost of the AIRS unit is under \$2.00/foot^2 for the black film hot air collector and under \$1.00/foot^2 for the integrated rock-storage and collection system. It is felt that at this price the AIRS unit will provide a practical low-cost alternative to drying crops using fossil fuels.

VI. SOLAR GREENHOUSE

The research on solar greenhouses and their application continued into 1976-77 along two paths. The first path was a scaling experiment based on the 8x8 modular greenhouse configuration. The second path was in the application area where an interstitial solar greenhouse was designed and built to house a methane generation plant and to supply the heating needs of the generator. To elaborate further on these parallel efforts we will begin with the scaling work since it was performed first.

In the work on the modular greenhouse it has been stressed that the basic structure could serve a multiplicity of purposes besides the obvious one of growing crops and to illustrate this a 3/8 scale version was designed, constructed, and evaluated specifically for crop drying. Since it was desired to optimize the structure for heat capture and retention, certain features existed in the dryer version which did not exist in the greenhouse version. The structure has the characteristic reflecting backwall, solid ends, and a double layer of PVC plastic covering. Suspended at three points on each end wall is a fifty-five gallon steel drum. The drum is painted flat black with an entrance door of wood on one end and an exterior control vent on the other end. The bottom half of the horizontal drum is filled with rocks as is the front section of the outer enclosure. The rocks are used to stabilize the temperature and to provide thermal storage for the night time portion of the drying cycle. The whole drying structure is oriented for maximum capture of the solar flux. In addition, a weighted, rubber covering is included to cover the structure after sunset. Tests have been run on the structure without rock storage, with 90 kg of rocks, and with 135 kg of rocks for extended periods of time. The results of tests taken on February 14, 1977 with 135 kg of rock storage are shown in the accompanying Figure 22. Included in the figure is a curve for the modular greenhouse for comparison. The data day began at 10:00 AM from a sub-freezing night. The peak solar insolation was about 610 watts per square meter. The greenhouse tracked the solar insolation quite closely in time which suggests that there is relatively little energy storage in the basic structure. The peak greenhouse temperature was 51.5°C or about 125°F. The peak dryer temperature occurred about 4 hours later as a result of the time delay stemming from the storage capacity of the rocks. The peak temperature inside the barrel was 29.5°C or about 85°F. The peak ambient temperature occurred about two hours after the greenhouse peak and was 20.5°C. One additional feature of the greenhouse curve should be explained and that is the relatively high night time temperature. This is not caused by storage but by a thermostatically controlled heater which was present for another experiment. Peak temperatures in excess of 180°F have been observed in the greenhouse during the summer months and 130°F during the winter months. These temperatures are good for drying certain crops but are not too well suited for growing purposes except for certain bacteria. The bacteria needed in methane biomass conversion thrive in the temperature range from about 90°F to 140°F and this knowledge led to the creation of an interstitial greenhouse.

The interstitial greenhouse is located in the small space between

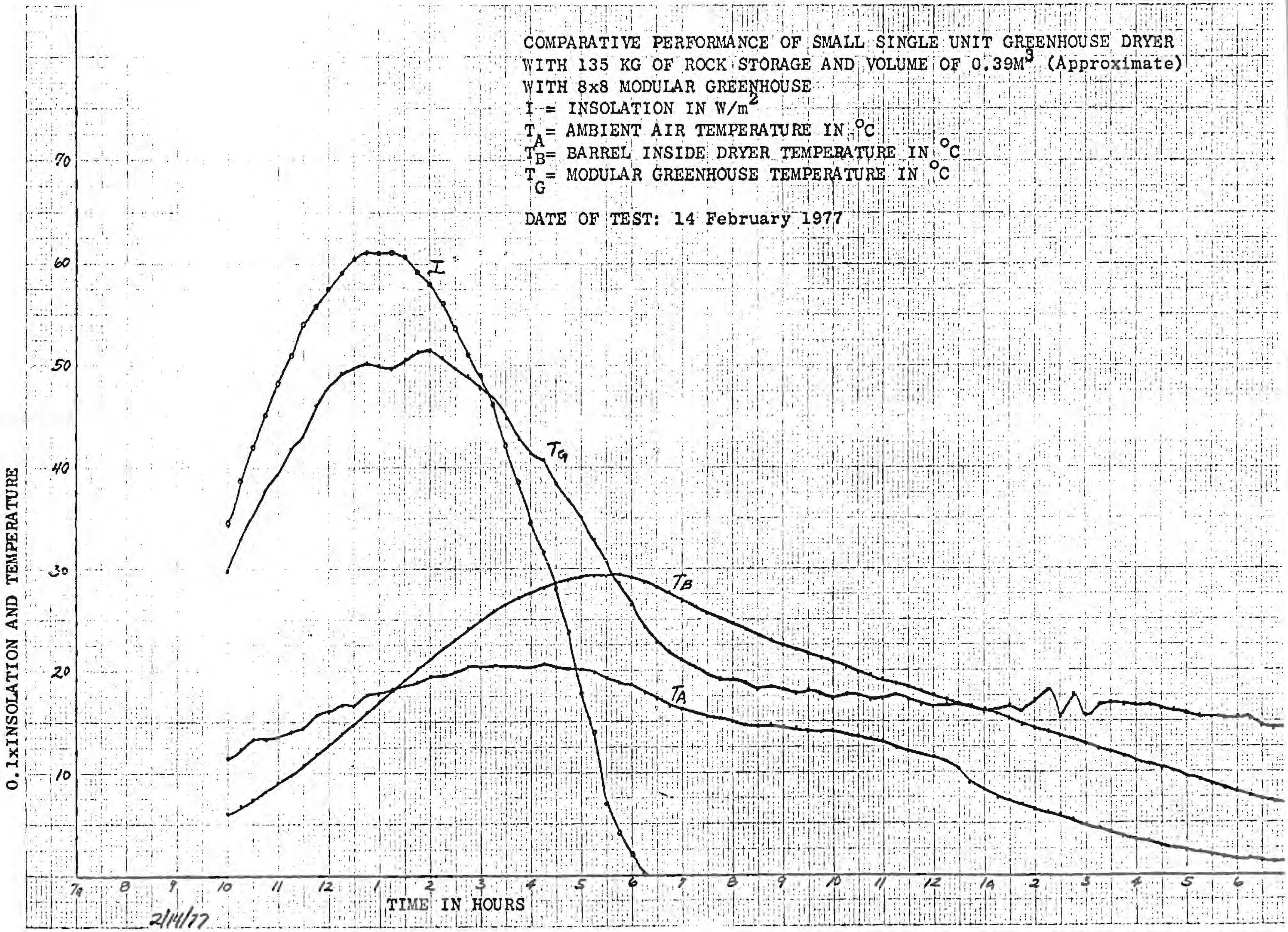

COMPARATIVE PERFORMANCE OF SMALL SINGLE UNIT GREENHOUSE DRYER
WITH 135 KG OF ROCK STORAGE AND VOLUME OF 0.39M^3 (Approximate)
WITH 8x8 MODULAR GREENHOUSE
I = INSOLATION IN W/m^2
T_A = AMBIENT AIR TEMPERATURE IN °C
T_B = BARREL INSIDE DRYER TEMPERATURE IN °C
T_G = MODULAR GREENHOUSE TEMPERATURE IN °C
DATE OF TEST: 14 February 1977
0.1xINSOLATION AND TEMPERATURE
TIME IN HOURS
I
T_G
T_B
T_A
10
20
30
40
50
60
70
7a
8
9
10
11
12
1
2
3
4
5
6
7
8
9
10
11
12
1a
2
3
4
5
6
2/14/77

FIGURE 23.

two modular greenhouses previously built and described in an earlier report. This greenhouse captures some sunlight but relies mainly on hot air generated in the modular greenhouses. The methane generator is located in this interstitial structure. It consists of a continuous feed/flush system with about a fifty-five gallon capacity. The air tight system utilizes a combination of chicken manure and green waste products (kitchen waste was used in the first run) for the feed material and produces three useful end products: (1) methane gas which can be burned for heating purposes; (2) a nitrogen rich liquid; and (3) a solid residue which could be used as a feed supplement. The gas is stored in the storage volume in the floor of the modular greenhouse and the liquid is pumped off and used as needed. The solid residue is allowed to accumulate and it too is pumped out of the system. It should be added that the solid residue appeared to consist mostly of wood chips so the digestion process of the kitchen waste and the chicken manure was essentially complete. Another load is being readied for processing.

VII. SOLAR POND

Shallow solar ponds measuring approximately 4 ft. x 14.5 ft. were constructed and tested in two different configurations. A blown polyethylene tube approximately 4 ft. wide was cut to a 15 ft. length and impulse sealed on both ends except for a small inlet and exit. This concept shows promise but our tests were conducted during the severe weather last winter and results are inconclusive.

A second pond was fabricated by Barco to the configuration shown in Figure 24. The bottom of the pond was 0.010 inch block vinyl and the top was of 0.010 inch clear vinyl. This bag was tested in May and June of 1977, and proved to be an excellent collector. Water temperatures of the vinyl collector could be controlled by the quantity of water put into the bag. Figure 25 is a photograph of the solar pond taken while it was being filled for testing.

Work during the previous reporting period demonstrated that shallow solar ponds look promising as solar collectors for agricultural dryers. The initial experimental work was done with a 1.5 ft. x 2.0 ft. pond whose depth and glazing could be quickly changed. The data from these tests were very encouraging, resulting in a design for a larger pond. While the small experimental pond could be fabricated with laboratory equipment, it was decided to have larger ponds fabricated by commercial firms not only because of the larger size, but because of the desirability of determining commercial feasibility and approximate production costs.

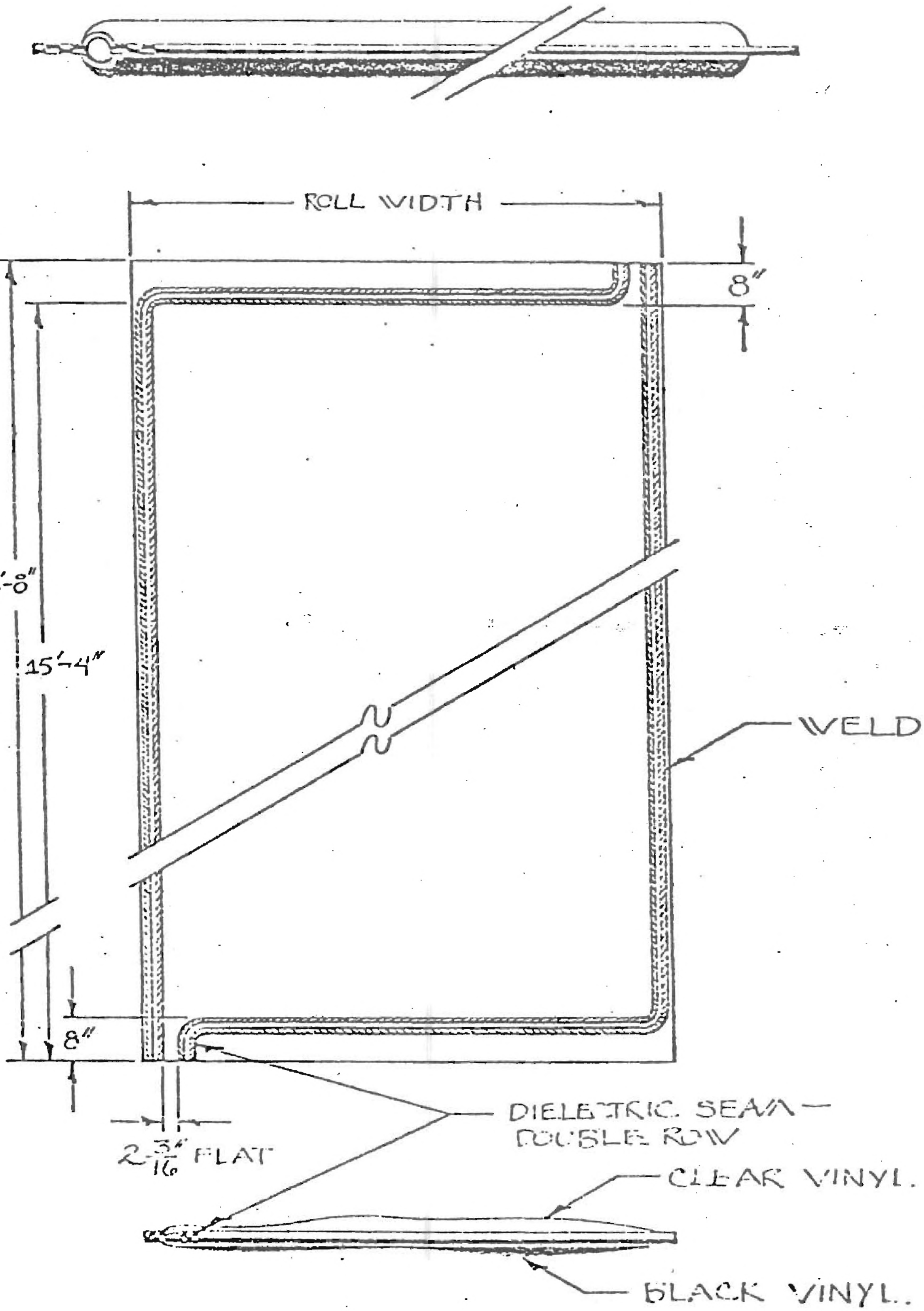


Figure 24. Vinyl Shallow Solar Pond

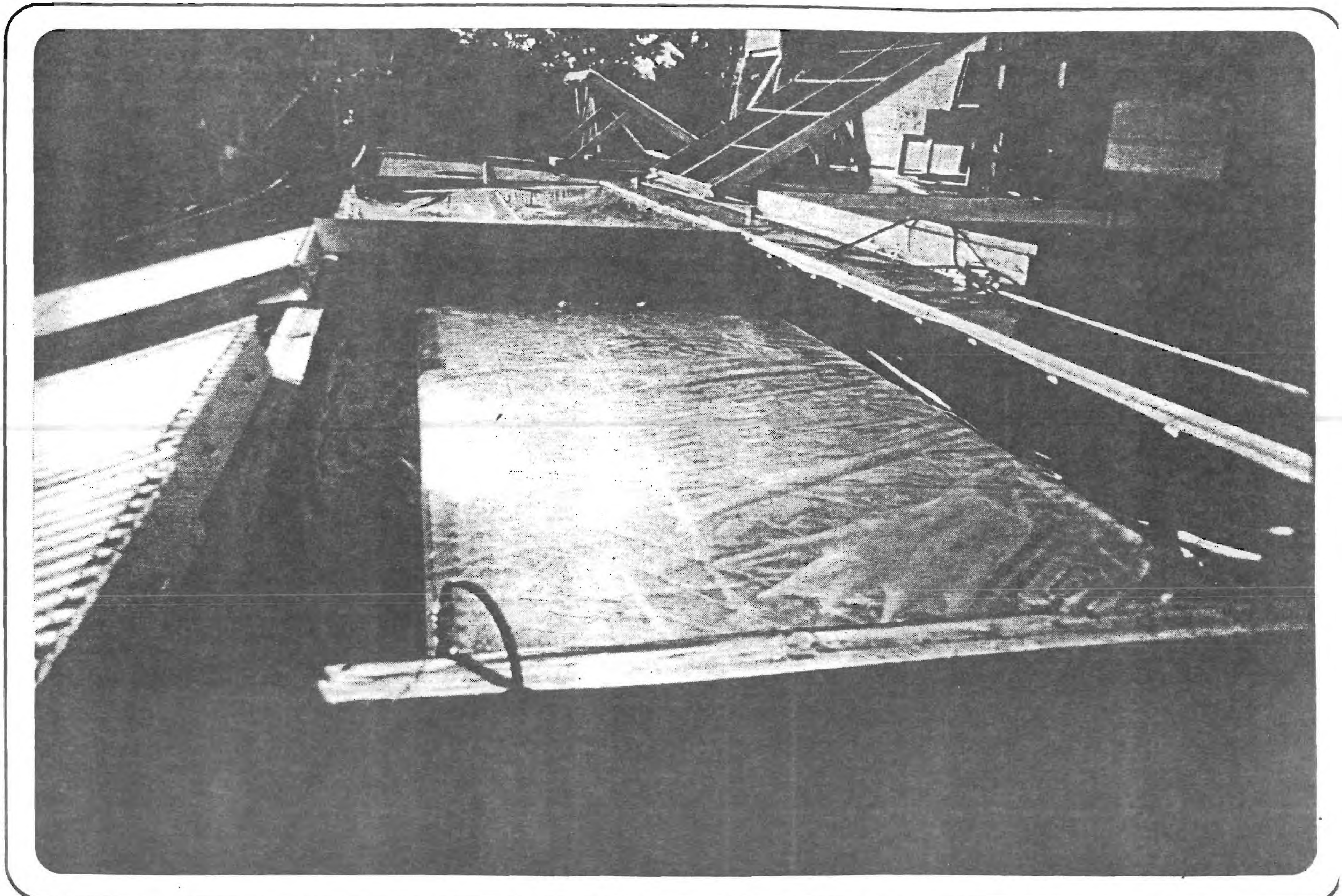


FIGURE 25
PHOTOGRAPH OF THE SOLAR POND BEING FILLED PRIOR TO BEING TESTED

Blown Polyethylene Shallow Pond

Blown polyethylene tubing is available from a large number of manufacturers in sizes from 6 inch lay-flat width to 19 feet lay-flat width and in lengths greater than 100 feet. This tubing is available in various thicknesses in both regular and U.V. resistant grades and is very modest in cost. U.V. resistant tubing cost approximately 7.5¢/ ft^2.

It was felt that these blown tubes may offer a very low cost method of fabricating a shallow solar pond even if they must be replaced every year or every two years.

A length of clear 0.010 inch polyethylene tubing with a lay-flat dimension of approximately 48 inches was obtained from PPD Corporation and cut to give a bag length of approximately 14.5 feet when filled to a depth of 6 inches. Each end of this tube was impulse sealed except for a small opening at each end. The finished bag looked like the vinyl bag shown in Figure 24.

Tests of the polyethylene pond were attempted in the very cold weather in late January and early February. The test results were inconclusive because the water froze before the bags could be covered and become collectors. The frozen water and the repeated handling eventually resulted in leaks which forced the tests to be halted.

The blown poly tube does look attractive and should be investigated further under test conditions which more nearly duplicate those under which the system would be operating when drying agricultural products. A clamping system is now available which eliminates the need to impulse seal the ends, thus greatly simplifying pond construction.

Vinyl Shallow Pond

An all vinyl shallow pond was fabricated by Barco to the configuration shown in Figure 24. The bottom of the bag was 0.010 inch black vinyl and the top was polished 0.010 inch clear vinyl. Barco double sealed each edge using a dielectric sealer. Barco estimates these bags could be produced for less than 50¢/ft^2 in 10,000 ft^2 quantities.

PVC tubing was inserted into the inlet and exit with screw type hose clamps holding the vinyl tightly to the PVC tubing. The bag was filled with 918 pounds of water resulting in a water depth of 3 inches. This proved to be too little water resulting in the water temperature climbing to well over 60°C (140°F). The water was increased to a depth of 6 inches resulting in a pond weight of 1836 pounds. The increased water mass resulted in maximum temperatures just about 50°C (122°F) which is considered a safe range for the vinyl.

Experimental Results

Figure 26 shows the performance of the vinyl shallow solar pond when filled to a depth of 3 inches. Figures 27, 28, 29 and 30 show the pond's performance when filled to a depth of 6 inches. Doubling the mass in the pond resulted in less than a 10°C (18°F) decrease in maximum pond temperature, increased collection capability and energy available for drying.

Conclusions and Recommendation

It is important to note that shallow solar ponds are inexpensive solar collectors and appear promising as agricultural dryers, if the

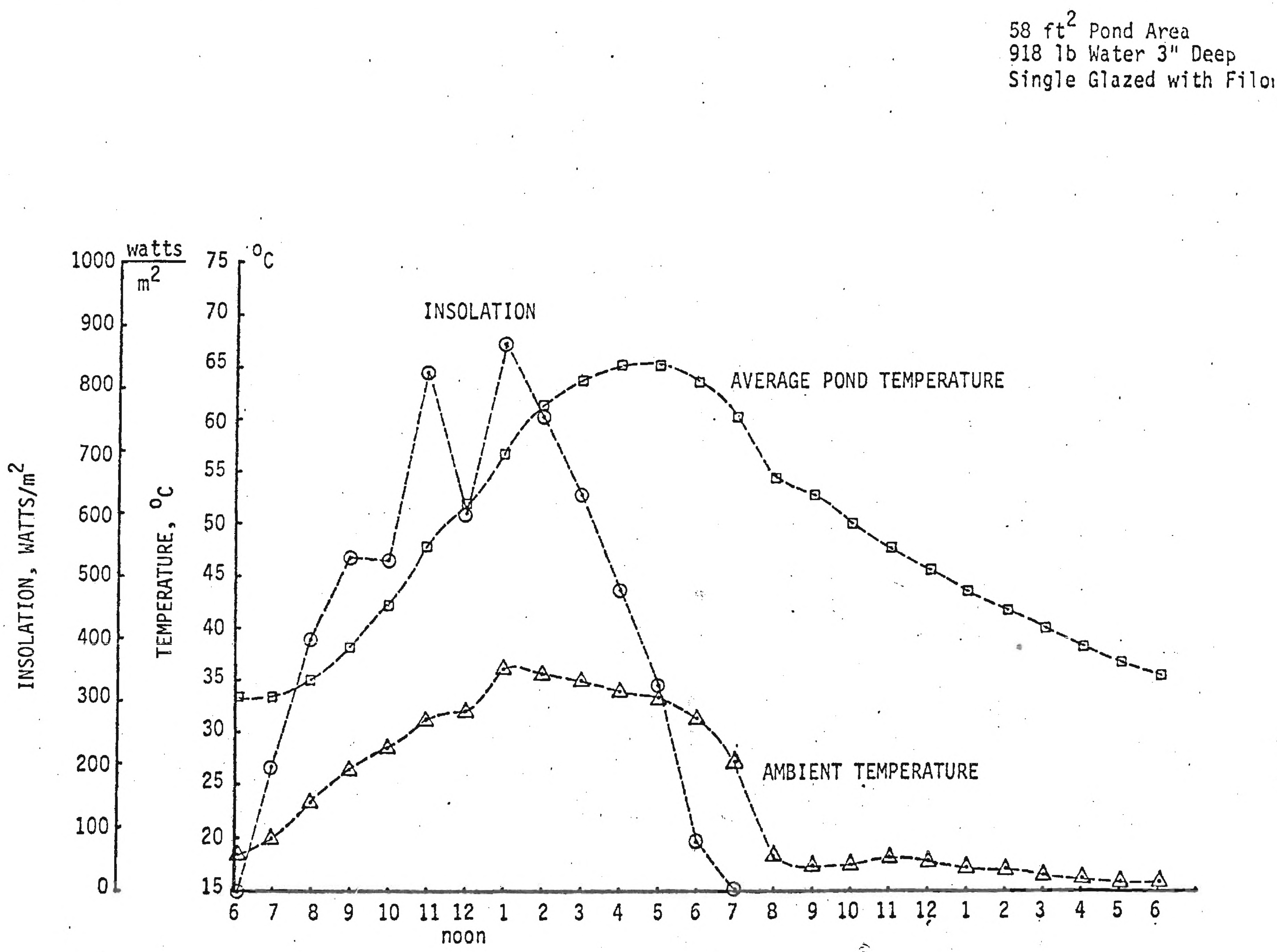


Figure 26. Performance of Shallow Solar Pond - 18 May 1977

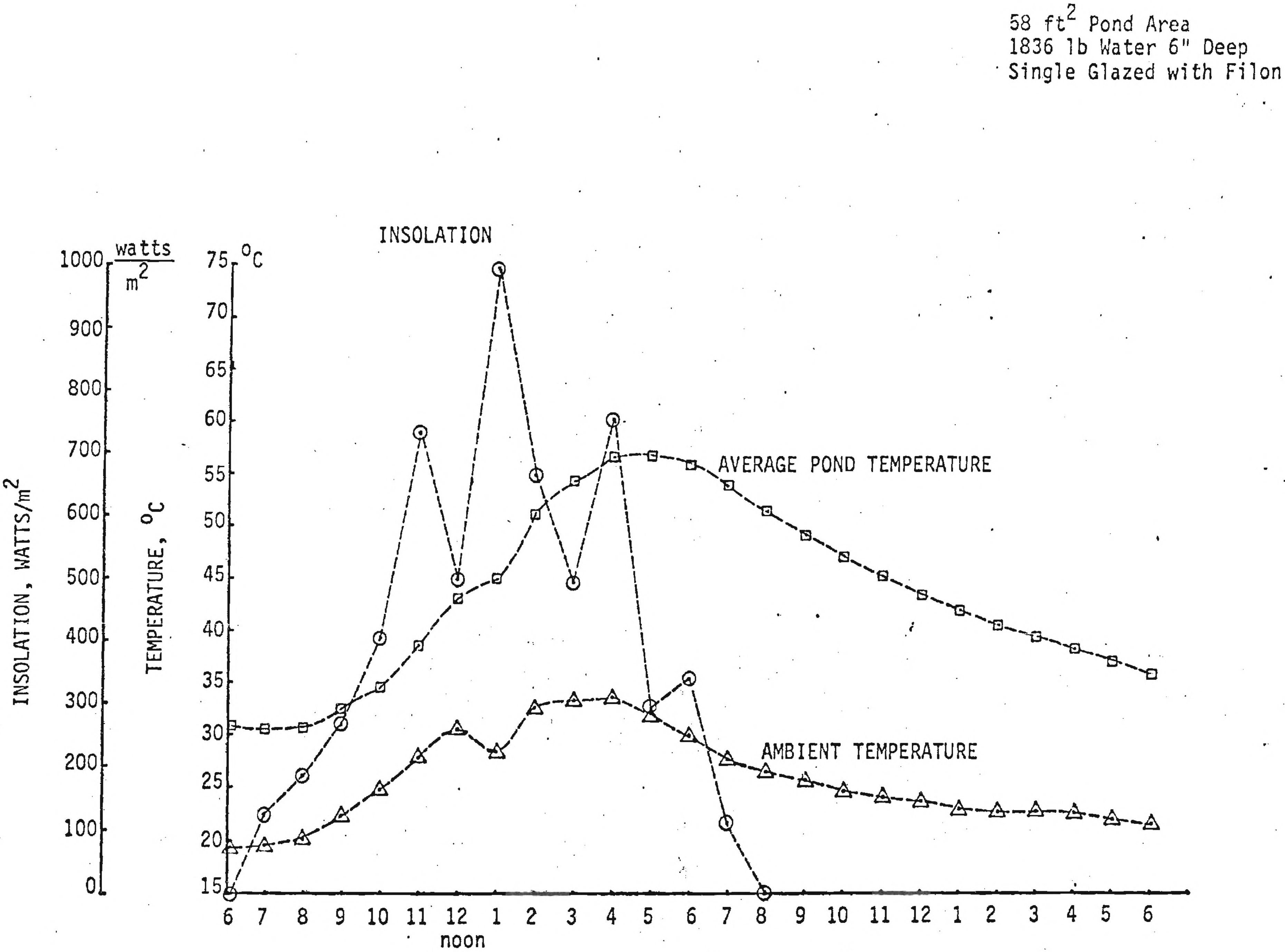


Figure 27. Performance of Shallow Solar Pond - 18 June 1977

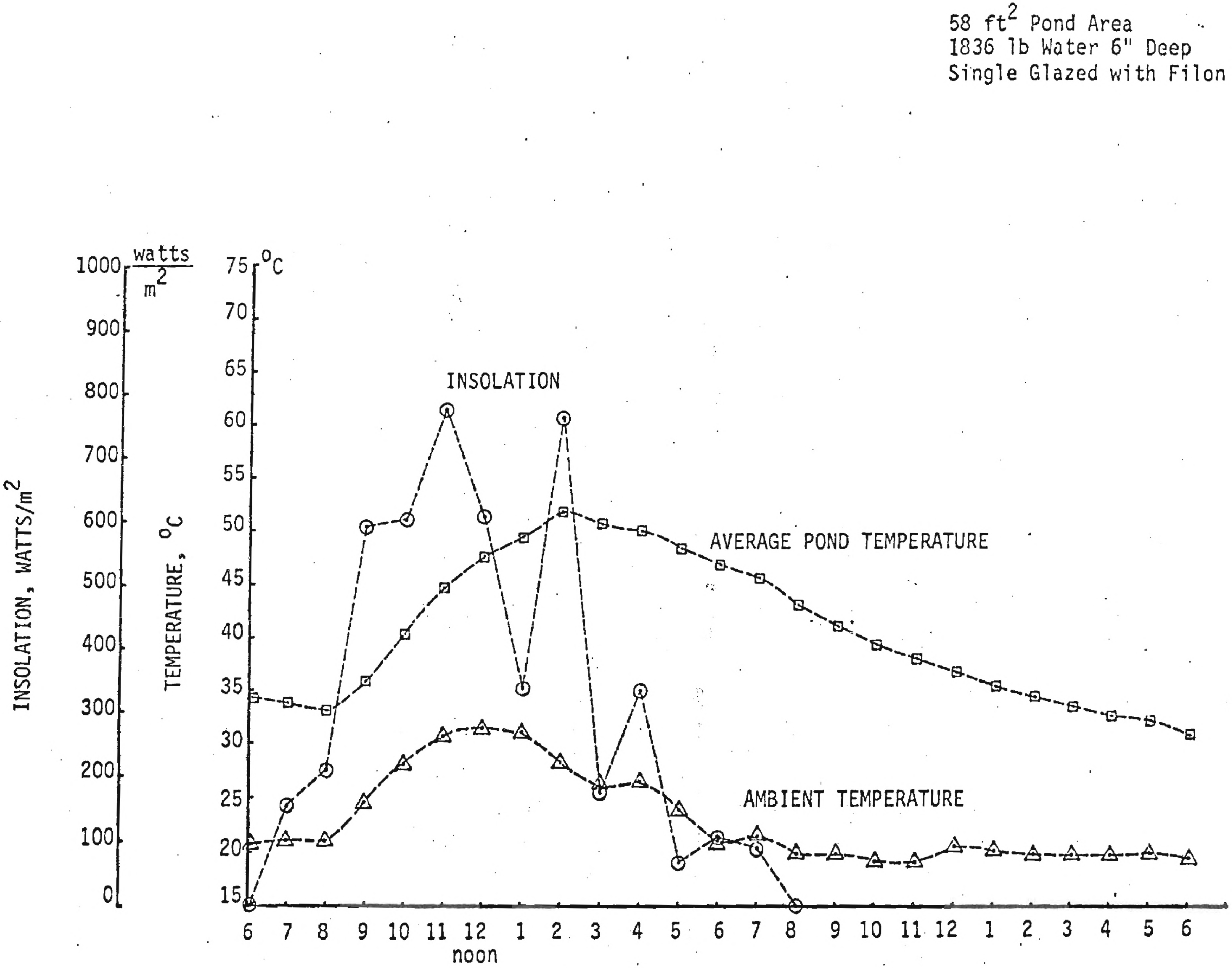


Figure 28. Performance of Shallow Solar Pond - 17 June 1977

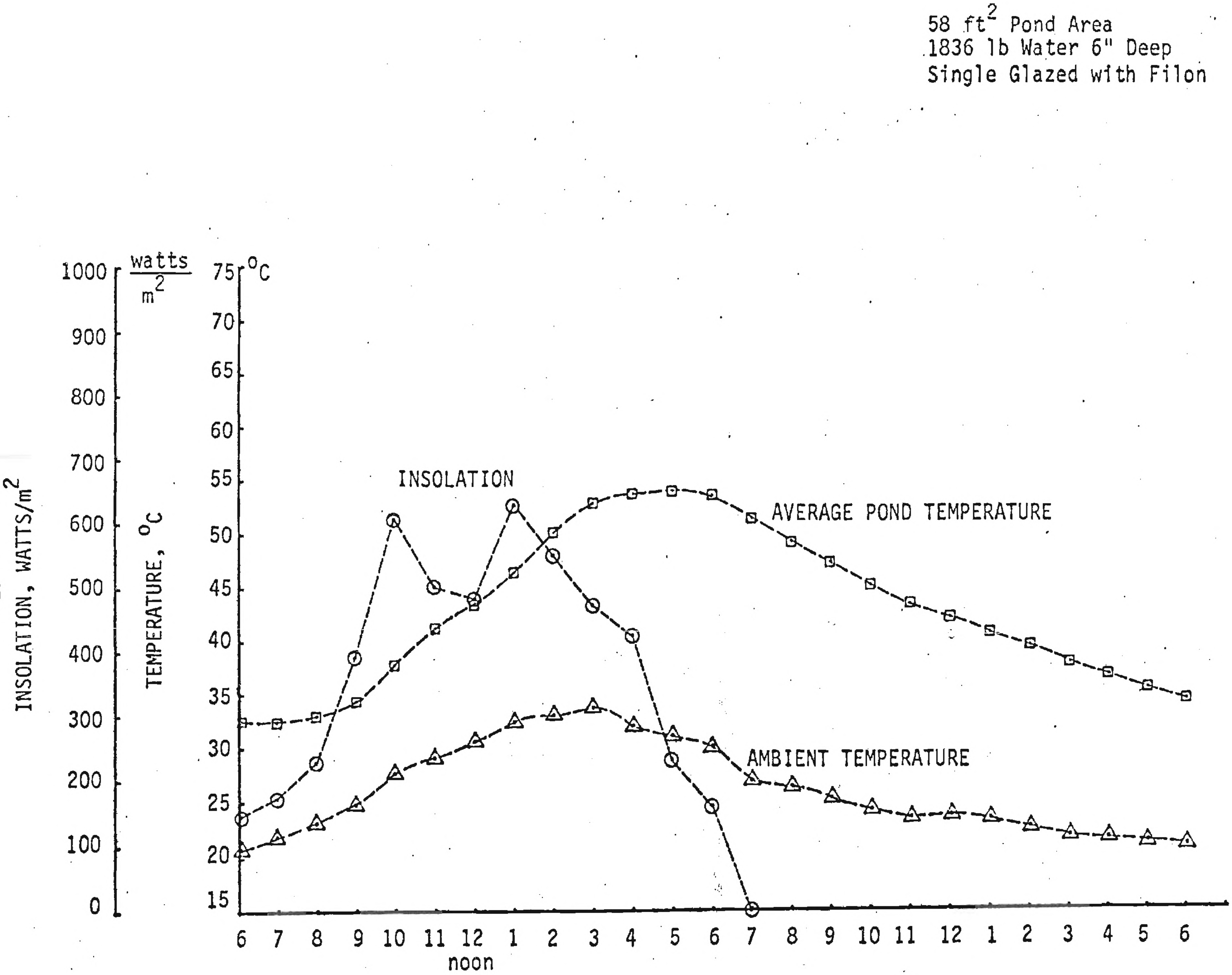


Figure 29. Performance of Shallow Solar Pond - 16 June 1977

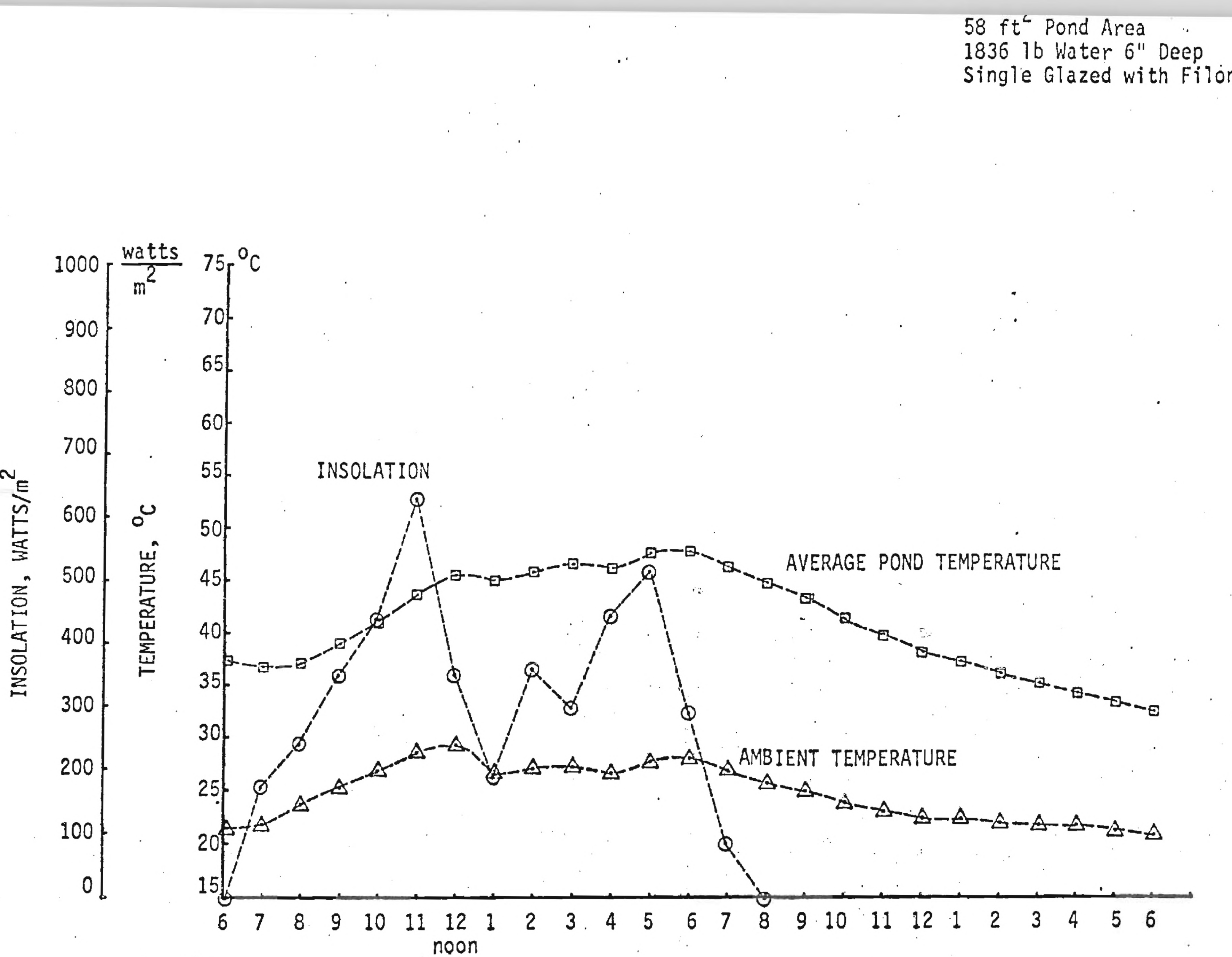


Figure 30. Performance of Shallow Solar Pond - 15 June 1977

pond is used properly. Because the pond has a relatively high loss coefficient, it loses significant energy at night. Proper use of the pond would be to use the energy during the day and early night when it is available rather than permit it to lose energy by overnight storage. Fortunately, this matches the energy demand of peanut dryers during much of the drying season.

It appears that the shallow solar pond for agricultural drying applications can be much simpler if operated as an air heater much like the solar rock collector. This involves pulling air over the top of the pond bag rather than pumping the water to a heat exchanger.

VIII. INSTRUMENTATION

The major thrust of the solar instrumentation effort this year has consisted of the conversion from a mini-computer to a micro-computer. The original system was a GRI-909. The new system is an Intellec-8 with 8K bits memory. It is more compact and more reliable than the GRI. All of the hardware and software modifications have been made to accomodate this change. Figure 31 is a photograph of the current data system.

In addition, an analog to digital converter has been interfaced to both the multiplexer and tape recorder.

A low cost humidity gauge has been designed and a protype unit has been built. A schematic of the gauge is given in Figure 32. It is estimated that the materials cost of this unit is under $200, and it can measure the dew point to ±2°C.

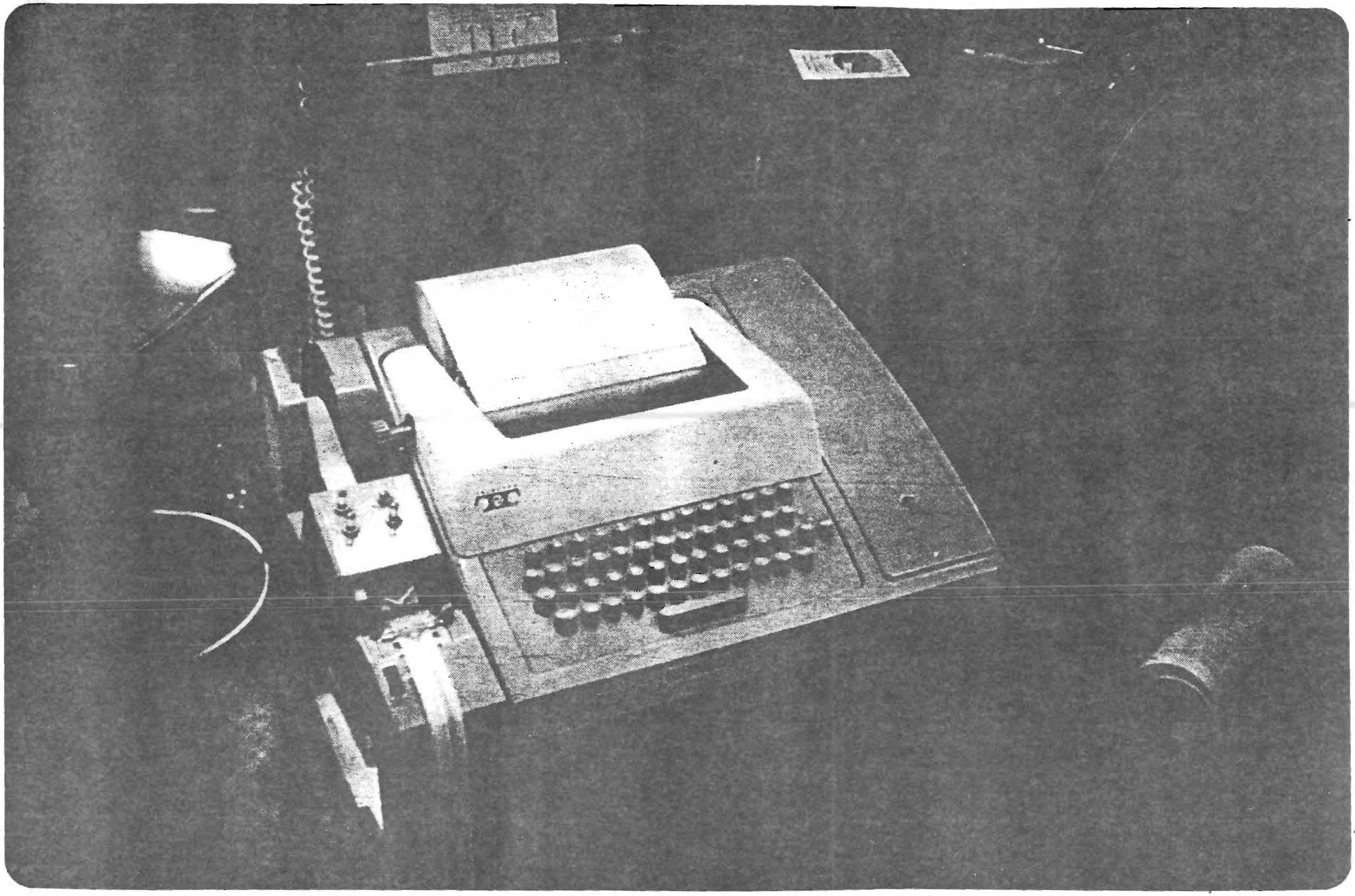


FIGURE 31
PHOTOGRAPH OF INSTRUMENTATION SHOWING TELYTYPE IN THE FOREGROUND AND INTELEC 8 MICROPROCESSOR IN THE BACKGROUND

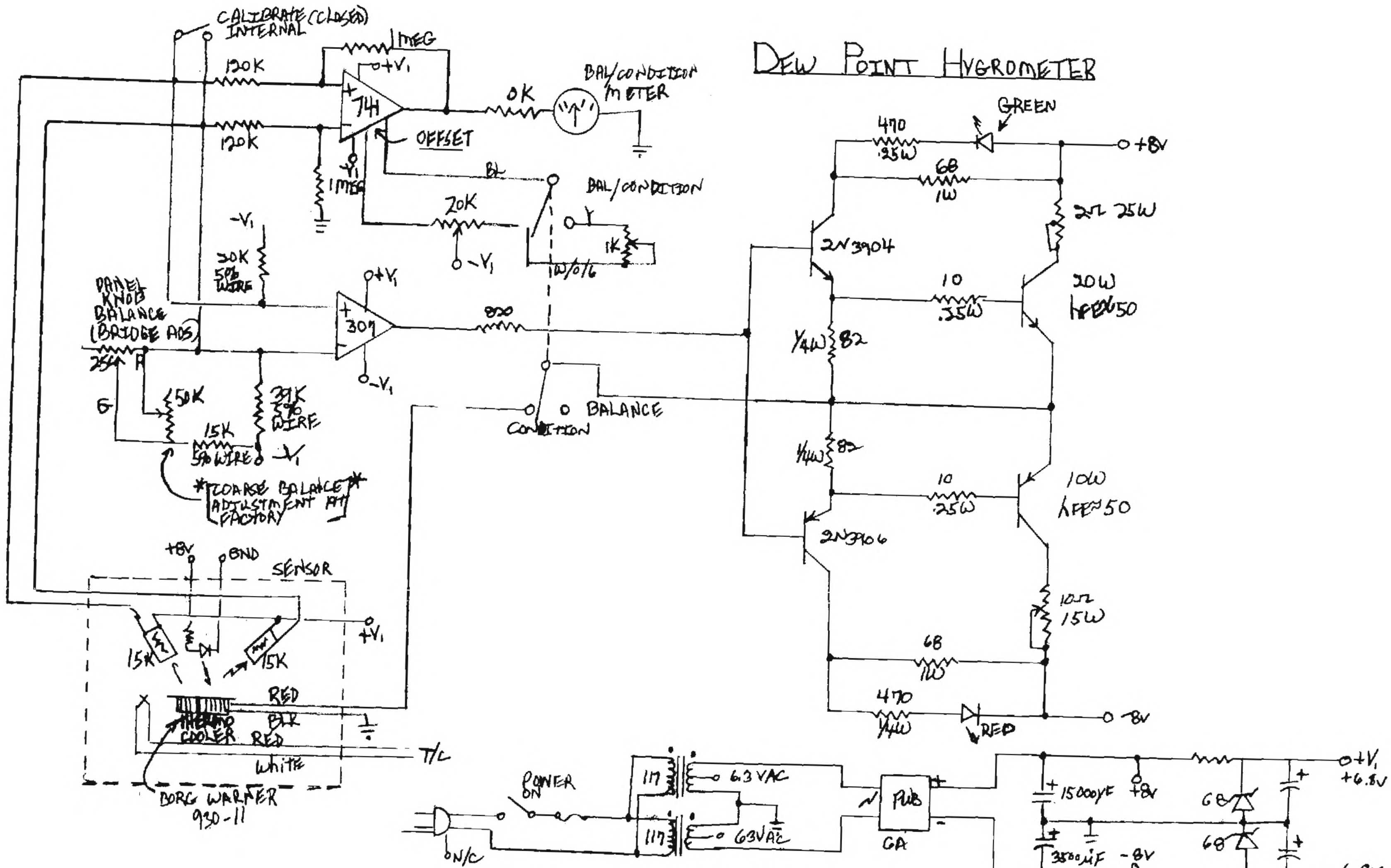


FIGURE 32
A SCHEMATIC OF THE LOW COST HUMIDITY GAUGE